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Development and Fabrication of Prototype Advanced Surfacing Systems for Military Use on Soils

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DEVELOPMENT AND FABRICATION OF PROTOTYPE ADVANCED SURFACING SYSTEMS FOR MILITARY USE ON SOILS

November 1972

An Investigation Conducted by

THE BOEING COMPANY
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13. ABSTRACT

Fiberglass reinforced resin surfacing materials were selected and verified, operational usage studies performed and two surfacing systems employing resin surfacing material were developed as a parallel effort: (1) a high rate system with truck mounted equipment; and (2) a low rate system with trailer mounted equipment. The high rate system has the capability to surface an area of 10,000 square feet with two pounds per square foot surfacing, within one hour and while utilizing not more than nine operating personnel The low rate system has the capability to surface an area of 2,000 square feet with two pounds per square foot surfacing, within one hour and while utilizing not more than five operating personnel. Each system has the capability to provide single or multi-layered surfacing or to utilize various weights and widths of fiberglass.

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Trailer Mounted Equipment						
Removable Pallet						
Rolling Equipment						
Single Layer Surfacing						
Multi-Layer Surfacing						
Polyester Resin						
Dimethyl Aniline Promoter						
Benzoyl Peroxide Catalyst						
Methylene Chloride Solvent						
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Prepared For:
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Port Hueneme, California

Contract Number N62399-71-C-0016

PRODUCT SUPPORT ENGINEERING

The Boeing Company Aerospace Group Research and Engineering Division

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1.0 INTRODUCTION

1.1 BACKGROUND

Considerable research and development effort has been expended during the past few years directed toward achieving an expedient surfacing material that can be rapidly applied and which will provide a high strength surface that is usable in a very short time (minutes) after emplacement. Such surfaces are particularly attractive for either military or civil usage where operations are conducted in remote areas and availability and transport of concrete or asphaltic materials pose unreasonable burdens, rapid reaction is required, and long term usage with no structural degradation is not a factor.

Starting in 1964 both The Boeing Company and LTV Aerospace Corporation conducted various expedient surfacing programs under government contract. Boeing, under contract to the U.S. Marine Corps, developed the "On Fast" fiberglass reinforced resin system. This system, employing chopped strand fiberglass matting, produced a surface of medium strength and, in which, cure could be effected at low temperature and in the presence of moisture. LTV, under contract to the U.S. Air Force, developed the "Rapid-Site" fiberglass reinforced resin system. This system, employing woven roving fiberglass matting, produced a surface of high strength but cure could not be effected at low temperature and in the presence of moisture. Both systems produced surfaces which showed great promise for uses such as roadways, helicopter pads, and storage and parking areas. The equipment developed by Boeing and LTV during the respective contracts, while generally satisfactory for constructing surfacing, pointed out the need for better integrated, production oriented equipment systems.

1.2 PROGRAM DESCRIPTION

As a follow-on to the above programs, U.S. Navy Contract N62399-71-C-0016 (Ref. 1) was implemented. This contract for development and fabrication of prototype advanced surfacing systems for military use on soils was administered by the U.S. Naval Civil Engineering Laboratory at Port Hueneme, California, with The Boeing Company, Seattle, Washington as contractor. Period of performance extended from June 1, 1971 through November 30, 1972. The contract specified that a surfacing material be selected and verified which would cure at low temperature and in the presence of moisture, similar to On-Fast, and contain high strength properties similar to Rapid-Site. The contract also specified that, based on operational usage studies, a high rate, truck mounted surfacing equipment system, and a low rate, trailer mounted equipment system be designed, developed, tested and delivered. These prototype equipment systems specifications required the equipment capability, versatility, and operational integration with inventory ancillary equipment which would be necessary for production systems. Additional program requirements included documentation and delivery of operation and maintenance manuals and preparation and delivery of drawings and specifications.

1.3 REPORT ORGANIZATION

This report of the program activities conducted under NCEL Contract N62399-71-C-0016 includes the major program activities reflected by the Boeing documents listed below and previously submitted to NCEL. Applicable sections of these documents are repeated in this report, with changes made where necessary for up-dating. Paragraph numbers have been changed to conform with the format of this report.

D180-12997-1, Revision A; Advanced Surfacing Systems Material System Selection and Verification (Reference 2).

D180-12989-1, Revision B; Advanced Surfacing Systems Operational Usage Study (Reference 3).

D180-14170-1, Revision A; Preliminary Design Data - Advanced Surfacing Systems (Reference 4).

D180-14261, Preliminary Design Data - Advanced Surfacing Systems (Reference 5).

D180-14507-1, Revision A; Test Plan - Advanced Surfacing Systems (Reference 6).

Additional areas of the report address equipment selection, procurement and fabrication; systems tests and demonstrations; equipment refurbishment and delivery; operation and maintenance manuals preparation; and drawings and specifications.

2.0 SUMMARY

2.1 Problem

The current concept of military equipment and personnel deployment requires the capability to provide rapid construction in remote or forward areas and is an aspect of Bare Base operations. Such construction includes vehicular operation and parking areas, material transfer and storage areas, helicopter pads, revetments, soil erosion prevention, sealing of sub-grades from water infiltration and other such uses. In many cases the remote locations where such construction is required, the requirement for rapid construction and immediate usage, as well as the limited requirements for permanency, preclude or do not warrant the use of conventional construction materials such as concrete or asphalt. Surfacing fabricated from woven wire matting, plastic trackways and metal sections have been used for rapid construction but with limited success. Components for connecting adjoining sections are subject to damage limiting the usable life of the surfacing and preventing the intended reuse in other areas. Also, such surfacing sections do not provide the required versatility for the wide range of construction required.

Past programs such as the U.S. Marine Coprs On-Fast and the U.S. Air Force Rapid-Site have demonstrated the feasibility of using on-site fabricated fiberglass reinforced resin laminates for the various types of construction noted above. Both On-Fast and Rapid-Site surfacing have desirable characteristics such as low temperature/moisture cure with On-Fast and high strength with Rapid-Site. However, a single surfacing had not been developed which emphasized low temperature/moisture cure capability combined with high strength. Also, the equipment systems developed during the On-Fast and Rapid-Site programs were not oriented to provide sustained high rate surfacing. Further effort was required to evolve integrated surfacing systems combining the best features of On-Fast and Rapid-Site, incorporating improvements identified during these programs, and based on planned operational usage.

2.2 Approach and Results

Due to the continued requirement for rapidly emplaced, quickly usable material for construction, and recognition of the high potential of fiberglassed reinforced resin, the development of advanced surfacing systems was undertaken. This development of advanced surfacing systems for military use on soils was performed by The Boeing Company under contract to the U.S. Naval Civil Engineering Laboratory, Port Hueneme, California, per Contract N62399-71-C-0016. The contract specified the selection and verification of a surfacing material system, operational usage studies, and development of both high rate and low rate surfacing equipment systems. The contract also specified extensive tests and demonstrations of performance capability with subsequent delivery of equipment. Preparation and delivery of operating and maintenance manuals and of drawings and specifications were included in the contract. Figure 1 indicates the basic program activities and time period. The various activities and results achieved are described below.

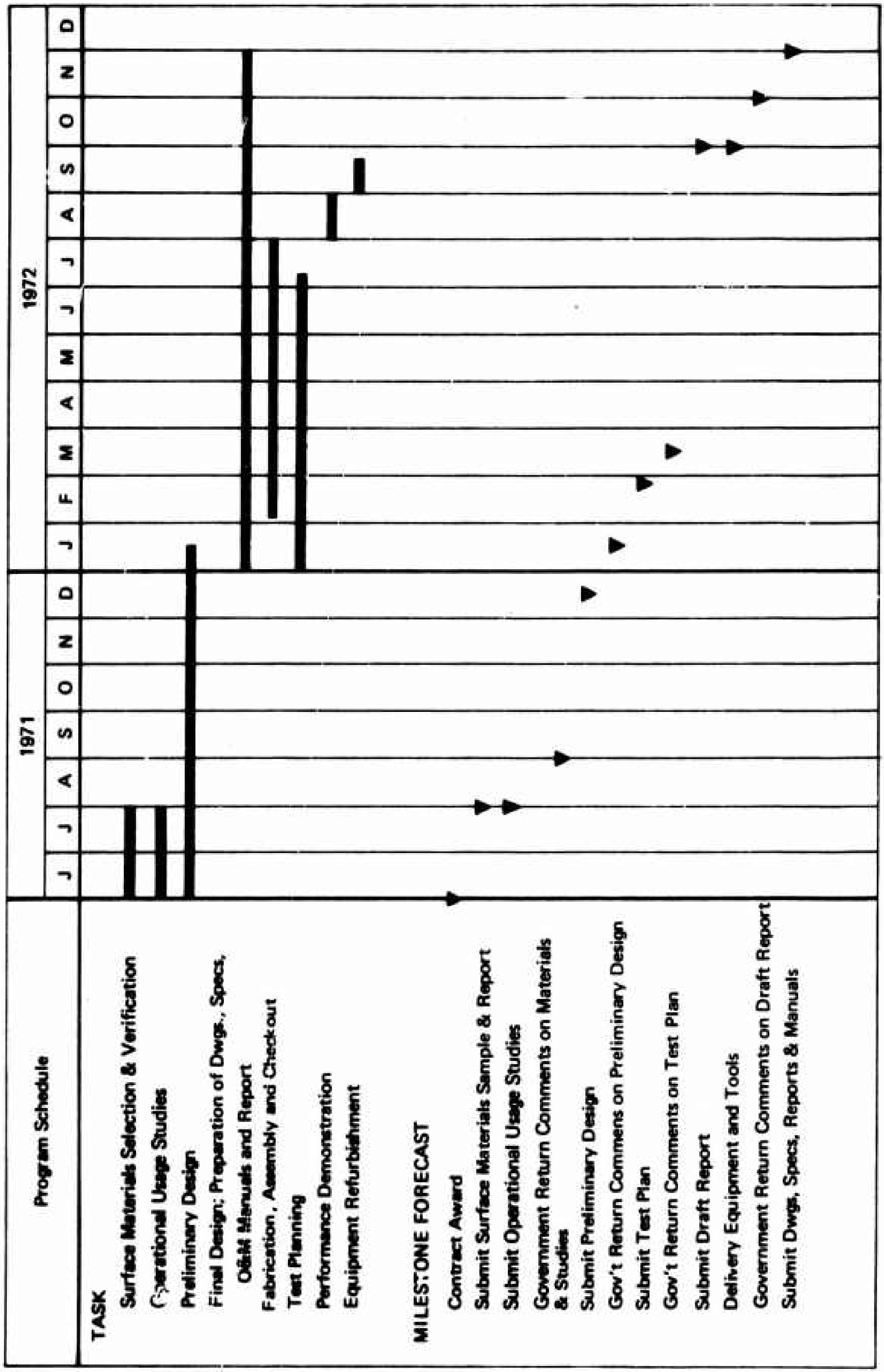


Figure 1 : DEVELOPMENT OF PROTOTYPE ADVANCED SURFACING SYSTEMS

2.2.1 MATERIALS SELECTION AND VERIFICATION

The first two months of the program were directed toward selecting and verifying by test, surfacing materials that would exhibit several specified properties. The basic of these were: (1) the ability to cure in not more than 60 minutes at 100% relative humidity and at any temperature from 40°F to 95°F; and (2) minimum strengths of 30,000 psi in flexure, 15,000 psi in tension, and 12,000 psi in shear. Strength deviations (standard) were not to exceed 25% of the average of 10 specimens. Additional defined properties were in regards to heat distortion, impact strength, abrasion resistance and absorption. A plan was prepared per Reference 2 which outlined a logical flow of events including materials selection, laboratory testing, field testing and reporting. Figure 2 illustrates this flow of events.

Based on previous experience and knowledge gained from both the On-Fast and Rapid-Site programs, it was possible to make an early selection of candidate materials with reasonable confidence that the required properties could be achieved. These materials were as follows:

Polyester Resin	-PPG Industries 5000 SC19-143 and Hooker Chemical Durez Division 26540
Reinforcement	- 40 oz. per square yard woven roving with 2 oz. per square foot chemically bonded chopped strand matting
Catalyst	- Noury Corporation 40% benzoyl peroxide emulsion (S0046 Green)
Promoter	- Dimethyl Aniline
Solvent	- Methylene Chloride

Satisfactory cure times were achieved. Laminates 12 inches x 12 inches and two pounds per square foot were made in the laboratory. The laminates were made from each of the resins mentioned above and were made both with and without rolling. In general, test specimens prepared from these laminates exhibited strengths in excess of those required. On the basis of these satisfactory laboratory specimens, effort proceeded in preparation of field applied surfacing samples. Specimens from an initial series of field applied surfacing exhibited satisfactory strengths with the exception of the low shear value obtained when using the Hooker 26540 resin. Samples of the initial field applied surfacing were sent to NCEL for specimen testing. NCEL test results showed low values in shear for specimens using Hooker 26540 resin, and low values in tension and shear for PPG Industries 5000 SC19-143 resin.

A second series of field applied surfacing samples was prepared. Test specimens prepared from this second series exhibited strengths appreciably above the stipulated minimum as indicated by tests performed both at Boeing and NCEL. Results of tests at Boeing are shown in Table 1. On the basis of these latter strength results and achieving the other required properties the materials were verified for use.

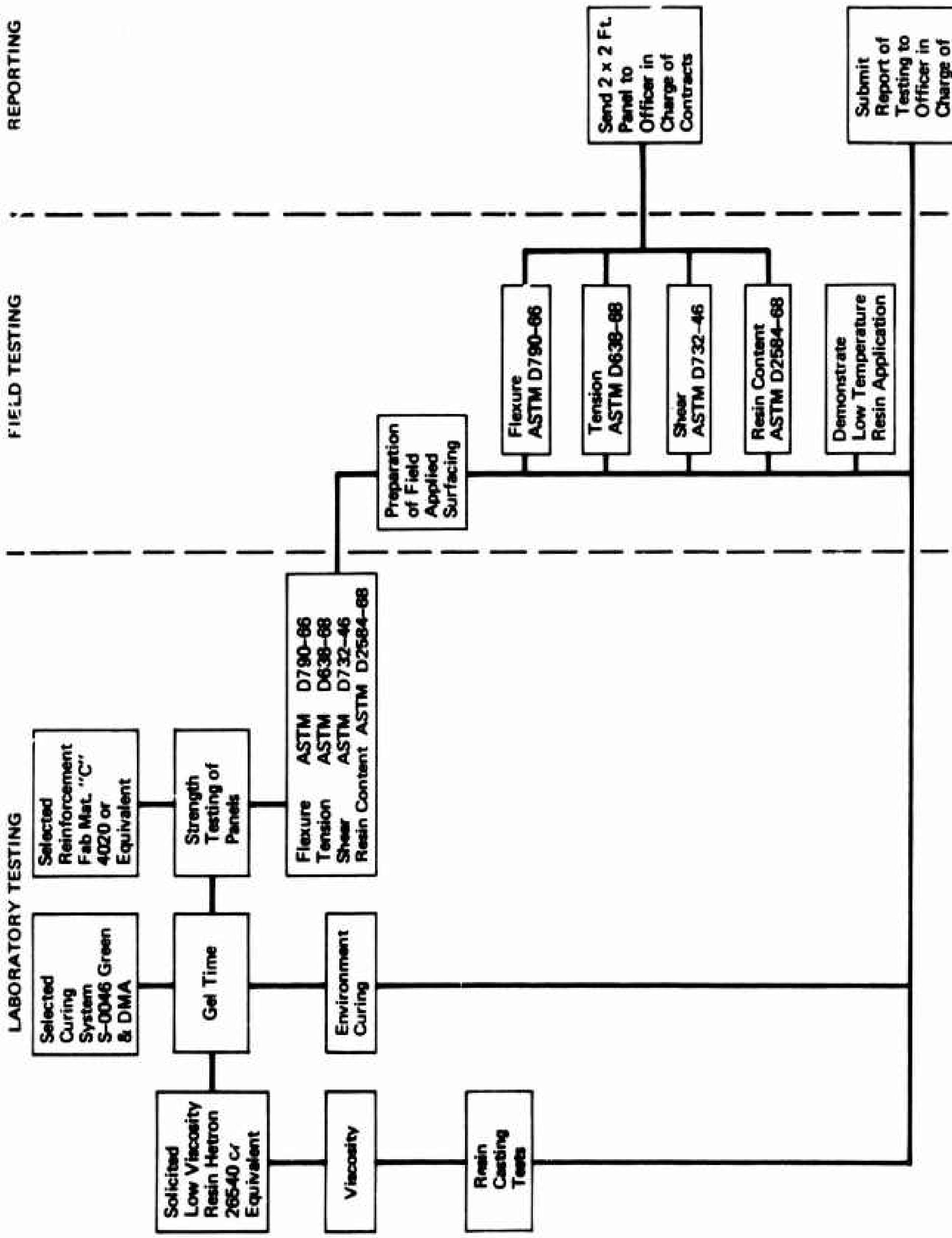


Figure 2: SURFACING MATERIALS VERIFICATION FLOW DIAGRAM

Table 1: SUMMARY – PANEL STRENGTH TEST RESULTS

Panel with Resin 26540

Property	Strength (psi)	Deviation (psi)
Flexure	42,882	4,679
Tension	20,572	2,172
Shear	14,532	842

Panel with Resin 5000 SC 19-143

Property	Strength (psi)	Deviation (psi)
Flexure	35,641	4,576
Tension	16,166	1,725
Shear	14,625	632

2.2.2 OPERATIONAL USAGE STUDIES

In addition to the materials selection and verification, the early portion of the program was devoted to preparing operational usage studies documented per Reference 3. These studies included the following.

- Surfacing application techniques and procedures
- Required amount of new development required
- Logistics aspects of equipment and materials
- Ecological considerations
- Personnel and ancillary equipment requirements
- Construction considerations such as lapping, expansion joints and edge anchoring

Results of the studies provided the baseline for system primary design approaches. Rate of surfacing was a critical requirement; 10,000 square feet per hour for the high rate system and 2,000 square feet per hour for the low rate system. Therefore, particular attention was given to vehicle speeds, materials dispensing rates, ancillary equipment deployment and personnel activities required to accomplish the surfacing rates. Typical areas to be surfaced were hypothesized such as indicated by Figures 3 and 4. Analyses, including "Time Lines," were made to define the equipment capabilities, material quantities and positioning, and personnel activities involved to assure meeting the surfacing rates. Results of such analyses indicated that it was possible to achieve the surfacing rates without posing unreasonable burdens on equipment or personnel. Ecological aspects and personnel safety considerations associated with use of the surfacing materials were also thoroughly investigated. Results of the investigations indicated that no pronounced adverse ecological conditions would occur if care was exercised in disposal of unused materials; also, by careful operation and observing prescribed precautionary safety rules, personnel safety would not be jeopardized.

In general, the operational usage studies proved to be very valuable throughout the development and test portion of the program. They served as a baseline for equipment design, test planning and test implementation. Success achieved during surfacing tests and demonstrations was due, in large measure, to the analyses made during the studies, and established their validity.

2.2.3 APPLICATION EQUIPMENT SYSTEMS DEVELOPMENT

Preliminary design of both the high rate and low rate application equipment was initiated immediately after contract award. Design proceeded in close coordination with the surfacing materials selection and verification and the operational usage studies due to the critical impact of these on the basic design. The preliminary design effort was divided into two phases and submittals to NCEL. The first phase delinated equipment design (Reference 4) to such a degree that after review, would enable NCEL to grant Boeing approval to procure long lead items from suppliers.

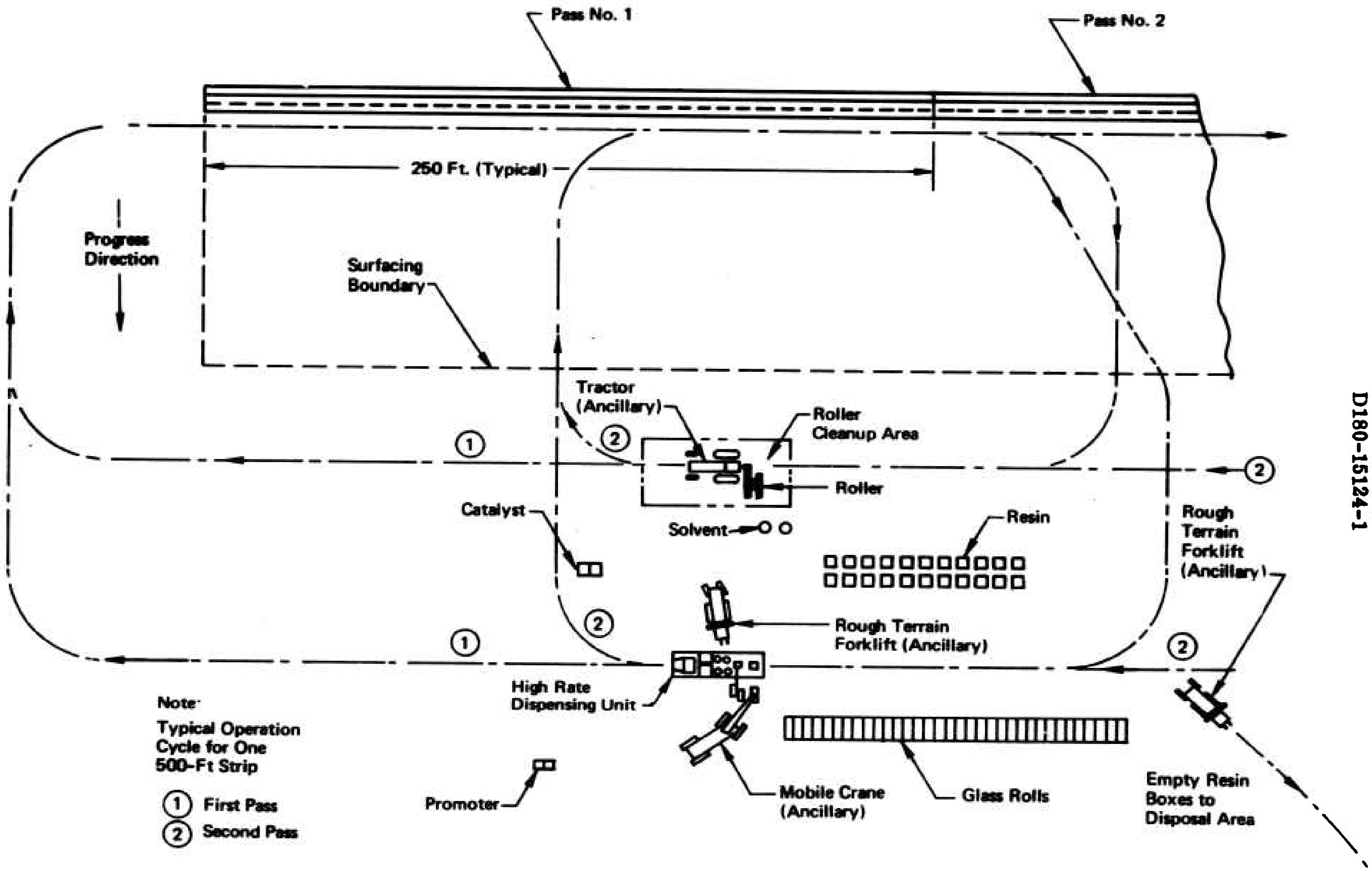


Figure 3: OPERATIONAL ARRANGEMENT – HIGH RATE SYSTEM (100 FT x 500 FT AREA)

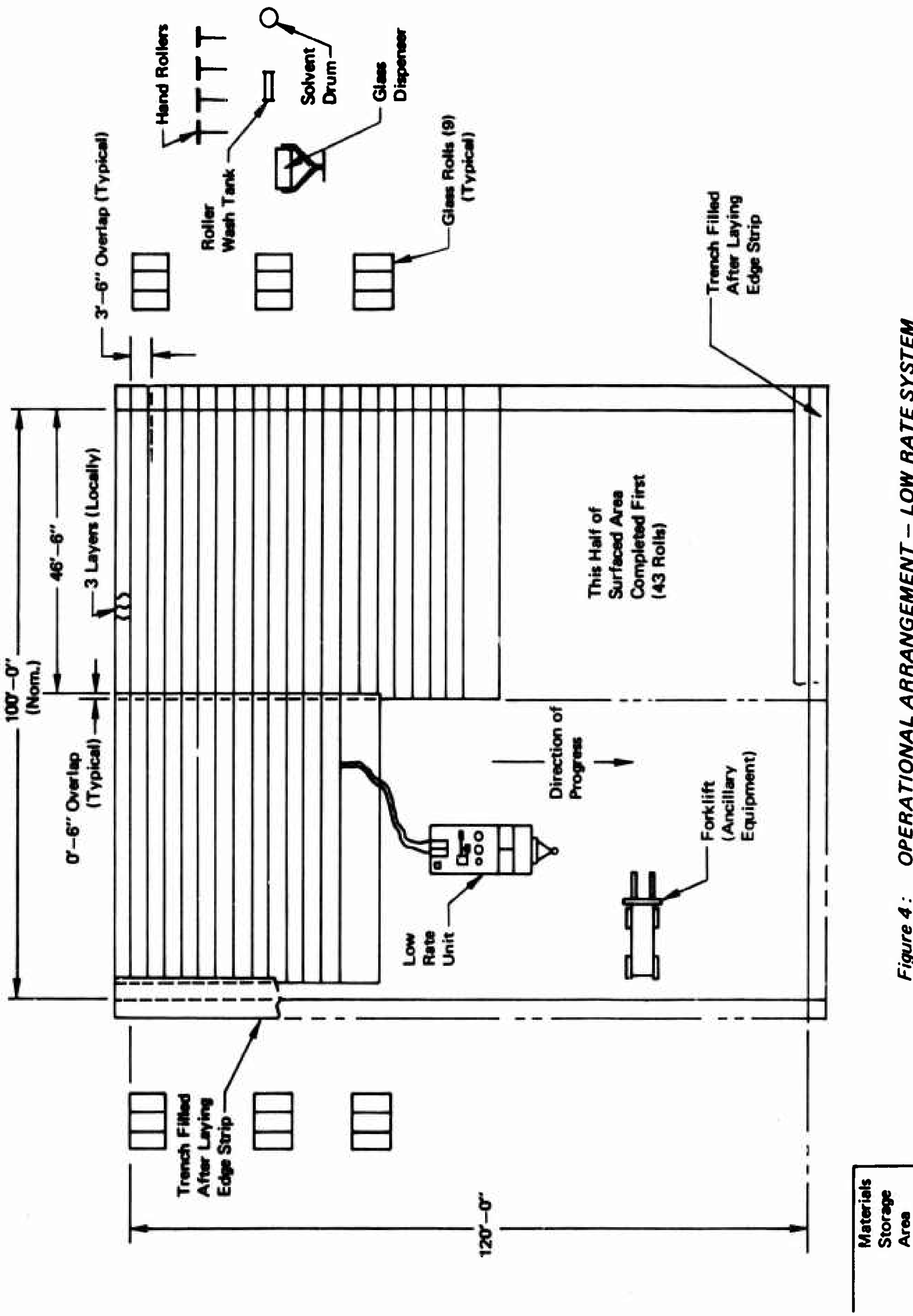


Figure 4: OPERATIONAL ARRANGEMENT — LOW RATE SYSTEM (100 FT x 120 FT AREA)

2.2.3 APPLICATION EQUIPMENT SYSTEMS DEVELOPMENT (Cont)

These items included truck, trailer, crane, and liquid dispensing systems engines and pumps. The second phase (Reference 5) completed delineation of design and after review and resolution of some questions, NCEL granted approval to proceed with system final design, fabrication and assembly. These activities commenced early in 1972 and were completed by mid 1972.

Fabrication of both the high rate and low rate system equipment was accomplished in a manufacturing area which was in close proximity to the design area thus minimizing coordination and liaison effort. No exotic manufacturing techniques were required since the designs specified the use of weldable steels and aluminums. The major items fabricated at Boeing were the high rate system support structure which mounts on the trcuk, fiberglass support structure, surfacing rollers assembly and the low rate system equipment removable pallet. Additional items included liquid containers, plumbing elements and miscellaneous bracketry. A large portion of the manufacturing effort was devoted to assembly, installation and check out. Figures 5 and 6 show typical fabrication and assembly operations.

Concurrent with the above activities, extensive liquid dispensing system development tests and evaluations were conducted for both high rate and low rate systems. Included in these were resin pumps performance verification, catalyst and promoter pumps performance verification and calibration, resin/catalyst and resin/promoter blenders selection and verification, and resin spray nozzles selection and verification. Also included were tests directed toward pumping and spraying resin having a viscosity of 1600 centipoises (CPS). Capability to accommodate this viscosity was a specific contract requirement. Figure 7 shows a test being conducted to evaluate spray nozzles.

Design, fabrication and assembly proceeded in a satisfactory manner with no significant problems, and on schedule. The long lead supplier items mentioned above arrived on schedule in most instances, with those arriving later than planned posing no overall schedule problems. Early check out of these items verified the expected performance and presented no problems relative to interfacing with Boeing fabricated components. One exception to contract specifications was the inability to provide trailer parking brakes meeting the requirements of MIL-M-008090E due to unavailability of components. Therefore, this requirement was waived for the prototype equipment and standard brake drums were supplied in lieu of brake drums that are demountable without disturbing the wheel bearings. However, adherence to the requirements of MIL-M-00809E was specified on the procurement drawings for follow on production.

Liquid dispensing system development tests yielded very satisfactory results and were in general accord with preceding analyses. The resin, catalyst, and promoter pumps exhibited reliable, consistent performance. The selected blending devices proved effective. Spray nozzles were selected which accommodated resin over the required viscosity range of 80 CPS to 1600 CPS.

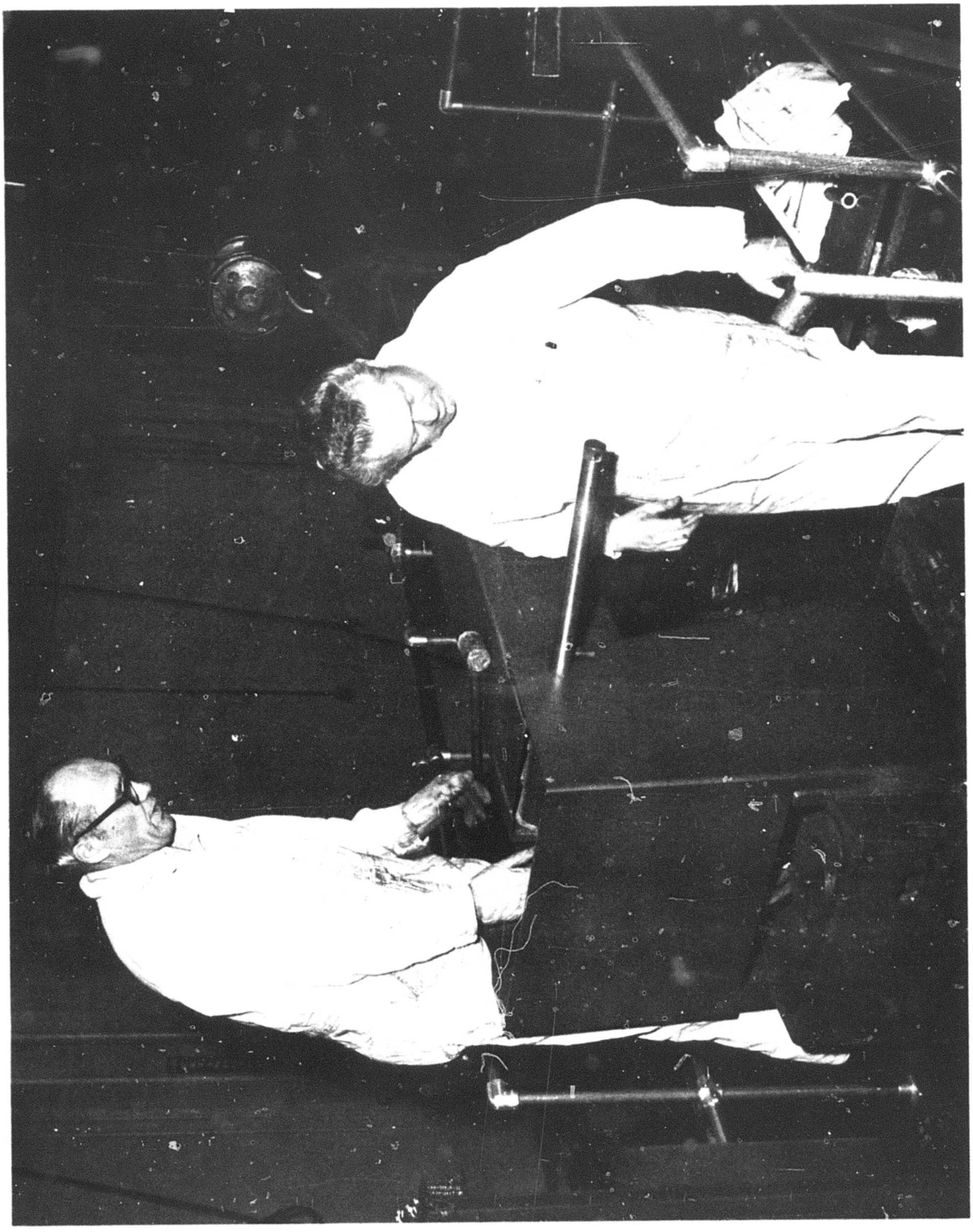


Figure 5: TURRET–BOOM ASSEMBLY

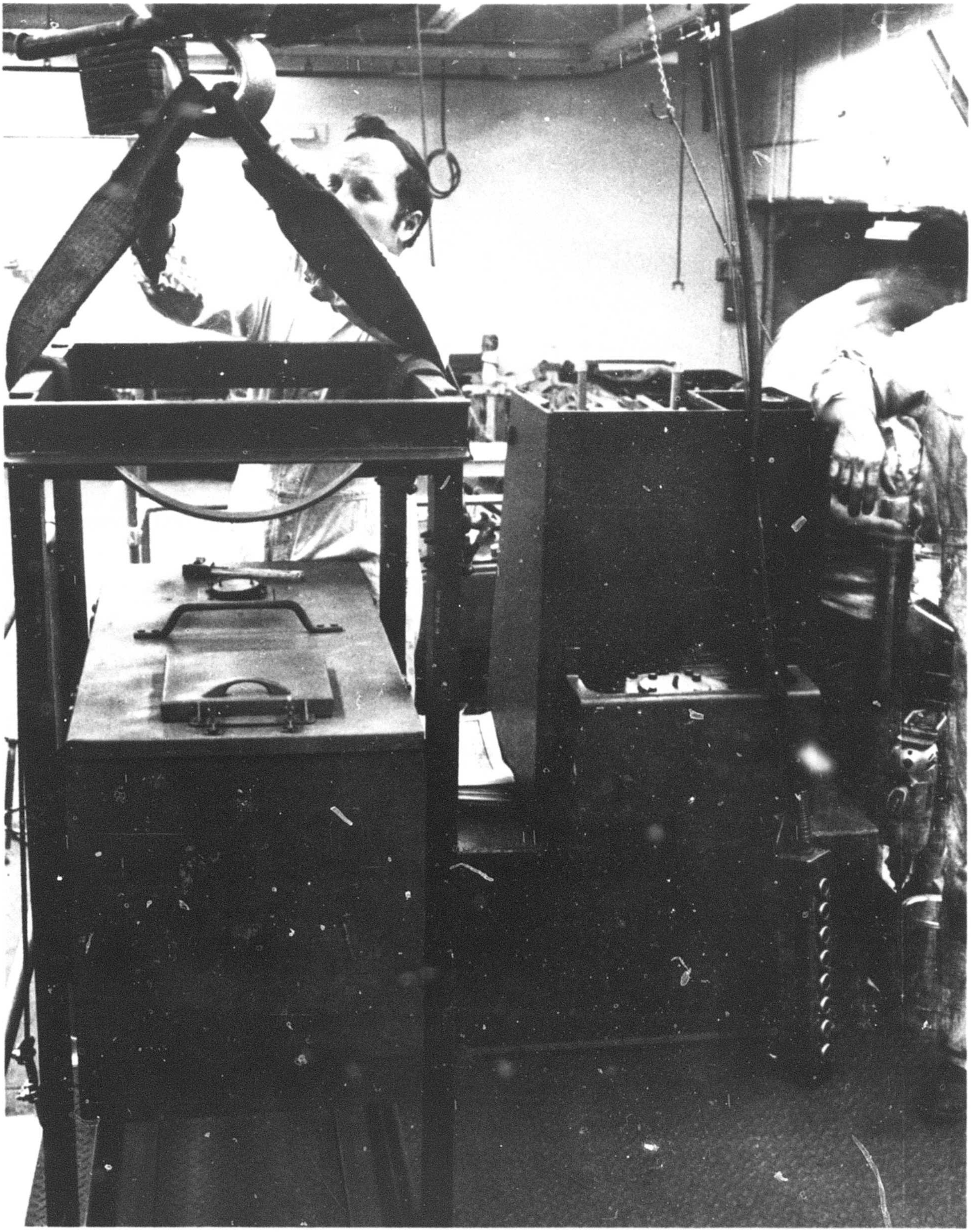


Figure 6: PROMOTER HOPPER INSTALLATION

Figure 7: NOZZLE TESTING

2.2.4 SYSTEMS TESTS AND DEMONSTRATIONS

The program required several tests and demonstrations to prove specified systems performance. Included in these were liquid systems pressure tests, continuous operational demonstrations, surfacing and associated tests, and mobility demonstrations. As a prelude to the tests and demonstrations, a test plan (Reference 6) was prepared. As required by contract, the plan described test approaches, methods, setups, procedures and instrumentation. Additional detail test planning was accomplished relative to test site selection and construction and task definitions. A team of operating personnel was formed and ancillary equipment selected.

The tests and demonstration commenced in early July, 1972 and, with the exception of the air transportability check, were completed on August 22, 1972. The air transportability check was conducted on September 15, 1972.

In general, the tests and demonstrations were very successful, with results showing good system performance. In all cases, where elapsed times were criteria, such as the surfacing square feet per hour, cleaning, and preparation for usage, the performance exceeded requirements. During demonstration of the high rate system, 10,500 square feet of two pounds per square foot surfacing was prepared in 46 minutes by nine operating personnel. During demonstration of the low rate system, approximately 5,070 square feet of two pounds per square foot surfacing was prepared in 2 hours and 5 minutes by five operating personnel. This latter rate is equivalent to 2,000 square feet in 50 minutes. In addition to these timed surfacing demonstrations, untimed surfacing demonstrations were conducted. During these untimed equipment capability demonstrations approximately 10,000 square feet and 5,000 square feet of additional surfacing was applied using the high rate and low rate equipment systems respectively. All surfacing constructed during the series of tests and demonstrations exhibited good cure, a generally good appearance, and was entirely usable. However, some wrinkling did occur and some scuffing was caused by the rolling equipment. Figures 8 and 9 show the high rate and low rate systems respectively during the untimed surfacing tests.

Some relatively minor problems and failures occurred during the overall test period. Flexible hoses on the liquid dispensing systems leaked during pressure testing and required replacement. A structural failure occurred on the high rate system rolling equipment and required redesign. The pump drive sprocket chain on the low rate system became disconnected at the end fasteners during surfacing and required reconnection. Other minor incidents occurred during mobility demonstrations and are described in detail further in the text.

Subsequent to the tests and demonstrations described above, the high rate and low rate application equipment was refurbished and prepared for delivery to NCEL. Little repair was required as a result of tests with the exception of the rolling equipment as noted in the previous paragraph. Refurbishment was confined principally to installation of minor items, cleaning and repainting. A check of the disassembly/reassembly requirements for air transport of the high rate system was performed during the refurbishment period. Time required to perform the disassembly/reassembly was within the one hour time limits specified.

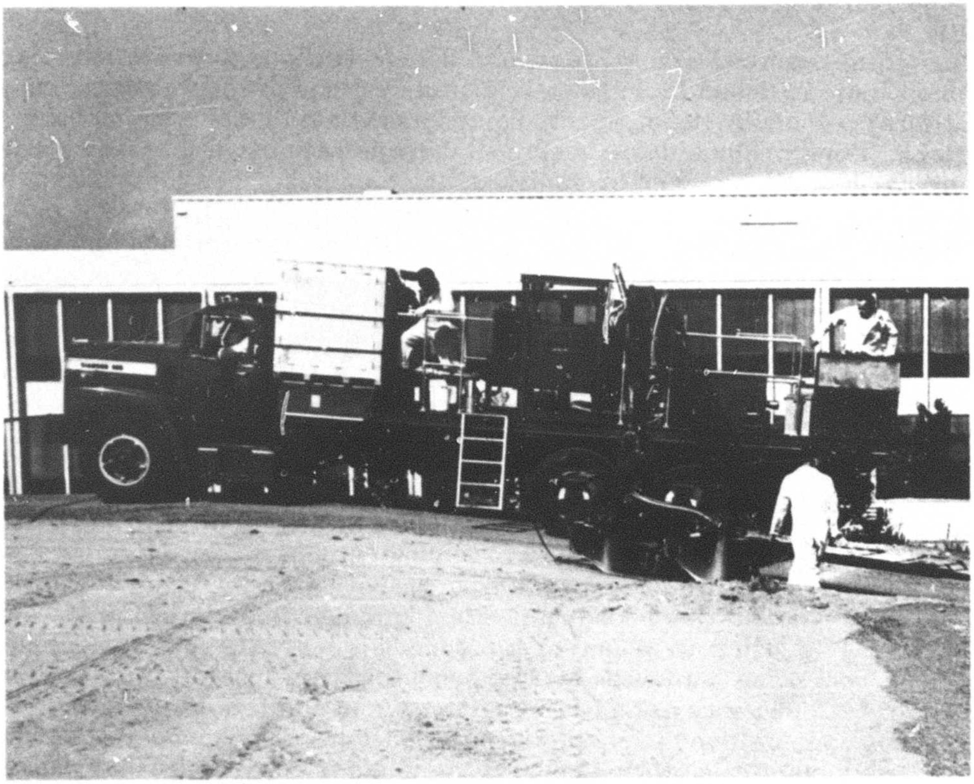


Figure 8 : HIGH RATE EQUIPMENT

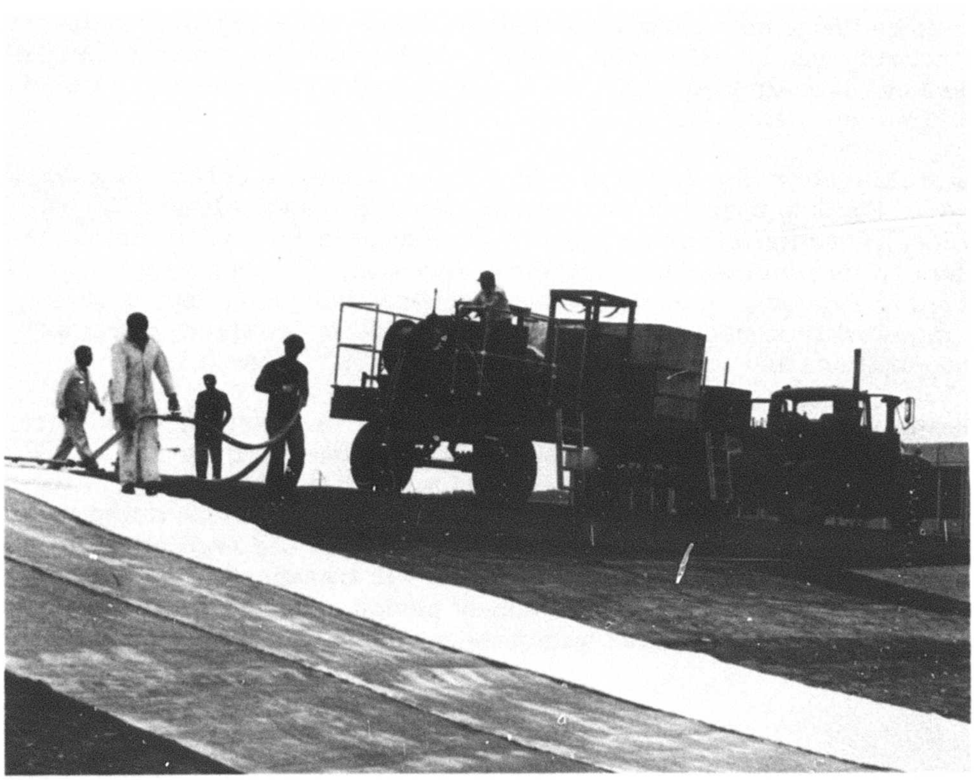


Figure 9 : LOW RATE EQUIPMENT

2.2.5 OPERATION AND MAINTENANCE MANUALS

The contract required the preparation and delivery of operation and maintenance manuals, suitable for use by military personnel, for both the high rate and low rate systems. It was specified that these manuals should describe and provide mixing instructions for the surfacing materials, the normal operating, maintenance and repair data applicable to such equipment, and recommended spare parts lists with prices.

The manuals were initially prepared such that pertinent information was available and the degree of completeness achieved, as necessary to support tests and demonstrations. Subsequently, draft copies were submitted to NCEL for general information purposes prior to submittal of final copies of the manuals.

2.2.6 DRAWINGS AND SPECIFICATIONS

In addition to the normal layout/design drawings and specifications required for system design and fabrication, the contract specified that drawings and specifications for follow on procurement be provided, and that they be in accordance with Category E, Form 2 of Military Specification MIL-D-1000. Both packages of drawings were to be delivered at the end of the program. Separate drawing packages were prepared for the high rate and low rate equipment systems. Also, specifications were prepared for the surfacing materials and materials packaging.

The layout/design drawings were executed on vellum for reasons of expediency and to facilitate making changes as design and fabrication progressed. The MIL-D-1000 drawings and specifications were executed on mylar with emphasis on refinement, neatness, and consistency in drawing practice. The MIL-D-1000 drawings and specifications submitted to NCEL at the conclusion of the program reflect the design changes accomplished and thought necessary as result of equipment fabrication and testing.

2.3 Conclusions

The selected surfacing materials consisting of woven roving fiberglass reinforcement, polyester resin, benzoyl peroxide-dimethyl aniline curing system, and methylene chloride solvent provide a satisfactory surfacing materials system. However, a liquid catalyst could offer advantages over the emulsified benzoyl-peroxide. Also, the woven roving fiberglass has inherent tendencies to wrinkle. The materials packaging concept, similar to that employed in On-Fast, is suited for military operational usage. Design of the resin container might be simplified by employing a single heavy gage plastic liner with integral shut off valve in lieu of the three thin plastic liners presently used.

The high rate and low rate prototype application equipment systems demonstrated overall satisfactory performance, including achieving required surfacing rates, surfacing versatility and mobility. Satisfactory surfacing can be consistently attained with the advanced system. However, some wrinkling is likely to occur, basically due to directional changes occurring during glass dispensing. Wrinkling can also occur when dispensing fiberglass over uneven ground surface. Wrinkling is also caused by the as manufactured configuration of the fiberglass. Based on performance of the prototype advanced surfacing systems, a follow on production program is warranted.

2.4 Recommendations

- Continue development of a liquid catalyst
- Investigate possible simplification and improvement of the resin container
- Investigate availability of fiberglass reinforcement which reduces surface wrinkling
- Implement a follow on production advanced surfacing systems program based on the prototypes and considering the above possible improvements

3.0 DISCUSSION

3.1 Background

There has been a long standing need by the military for an expedient material that could be used for surfacing or other construction in remote areas where use of conventional materials such as concrete or asphalt is not feasible. Requirements for an expedient material are directly related to the Bare Base concept of deployment. Basic characteristics of such a material should include the following.

- Minimum logistics burden in transport to remote areas
- Capable of rapid emplacement under a wide range of environmental conditions and of being usable in minutes after emplacement
- High strength and reasonable durability
- Adaptable to a wide range of uses such as roadways, helicopter pads, aircraft aprons and taxiways, storage and transfer areas, revetments, soil erosion prevention, and water containment for nonpotable water
- As low in cost as possible, commensurate with other requirements

Several types of expedient surfacing materials have been developed, placed in inventory, and been subjected to operational evaluations. Included in these are woven wire matting, plastic trackways and metal planking. While these have exhibited capability to carry traffic over poor subgrades, they have tendencies to fail at section connectors, with the intended reuse rendered either impractical or impossible. Cost of such materials is high and construction use is limited compared to on site fabricated material which can be employed for many uses such as revetment covering, erosion prevention, subgrade sealing and water containment in addition to surfacing for vehicular traffic.

As a supplemental or replacement material for the prefabricated sections mentioned above, on site fabricated, rapid curing reinforced plastics have shown great promise. Both the on site fabricated On-Fast, developed for the U.S. Marine Corps by Boeing, and Rapid-Site, developed for the U.S. Air Force by LTV, employed fiberglass reinforced polyester resin. Both materials were adaptable to a wide range of uses. However, both the On-Fast and Rapid-Site systems, including surfacing materials used and surfacing application equipment, were limited relative to desired operational requirements. The On-Fast surfacing material had good curing characteristics but lacked the desired directional strength. The Rapid-Site surfacing material had high strength but cure was inhibited by moisture and low temperature. Neither the On-Fast nor the Rapid-Site application equipment had the degree of integration and the surfacing rate capability required for operational systems.

3.1 BACKGROUND (Cont)

As a further step toward achieving operational systems, the Advanced Surfacing Systems Program was implemented per NCEL Contract N62399-71-C-0016. The contract specified the selection and verification of a surfacing materials system which reflected the requirements for high strength and capability to cure at low temperature and in the presence of moisture. The contract also specified the development of a prototype high rate and a low rate application equipment system. This development with related design features was to be based on operational usage studies. In addition to the equipment design, fabrication, tests and delivery associated with development; the contract specified compilation and delivery of operation and maintenance manuals, drawings and specifications, and program reports.

3.2 Materials Selection and Verification

The selection and verification of surfacing materials for use in the Advanced Surfacing Systems was based on a review of the materials used in previously developed surfacing systems (refer to Section 3.1) as well as the materials requirements set forth in NCEL Contract N62399-71-C-0016 (Reference 1).

The materials selected initially for testing were those that appeared to offer a distinct advantage in meeting the required field strengths and cure times. A woven roving reinforcement such as that used in the Rapid-Site system, combined with low viscosity polyester resins was selected in order to achieve minimum field applied surfacing strength requirements of 30,000 psi (flexure), 15,000 psi (tension), and 12,000 psi (shear). The resin curing system used in the On-Fast system (benzoyl peroxide catalyst and dimethyl-aniline promoter) was selected in order to obtain a maximum field cure time of 30 to 60 minutes when applying surfacing at any relative humidity and at any ambient temperature from 40°F to 95°F.

In addition to selecting and verifying materials for the Advanced Surfacing Systems, the work accomplished and results obtained during this portion of the program were coordinated with and used as data points where applicable in the Operational Usage Study (Reference 3).

3.2.1 SURFACING MATERIALS SELECTION

Although the same basic materials (i.e., polyester resin and fiberglass reinforcement) form the basis of the On-Fast and Rapid-Site material system, neither material system as defined met the stated performance requirements as regards to both cure time and strength. While the On-Fast material system is capable of rapid cure in a moist, low temperature environment, the cured surfacing does not possess the directional strength capability of the Rapid-Site material system because of the non-directional chopped strand fiberglass matting used for the reinforcement material. Conversely, the Rapid-Site material system does not cure under cold, wet conditions but does possess better directional strength than the On-Fast material system due to the use of a woven roving fiberglass reinforcement material. Because of these known properties and characteristics of existing material systems, the following were selected as the basis for the surfacing materials.

3.2.1 SURFACING MATERIALS SELECTION (Cont)

- Low Viscosity Resins-- PPG Industries 5000 SC19-143 and/or Hooker Chemical Durez Division 26540.
- Reinforcement--40 oz per square yard woven roving with 18 oz per square yard chemically bonded chopped strand matting.
- Promoter and Cataylst--Dimethyl aniline and 40% Benzoyl paroxide emulsion
- Solvent--Methylene Chloride

3.2.1.1 Curing System

To initiate polyester resin polymerization at ambient temperatures, two curing systems are commonly used by the plastics industry. They are benzoyl peroxide type catalysts/dimethyl aniline promoter which was, as previously noted, used for the On-Fast system and ketone peroxide type catalyst/cobalt napthenate promoter which was used in the Rapid-Site system. If a slow resin gel time is desired, the ketone peroxide catalyst/cobalt napthenate promoter system is normally used. However, both catalyst/promoter systems can be used to rapidly gel and cure polyester resins under normal room temperature and humidity conditions.

During the early phases of the On-Fast program Boeing developed a screening test to evaluate the relative effectiveness of resin curing systems in the presence of moisture. The results consistently obtained from this test show that environment has a marked influence on the degree of resin cure obtained with a particular resin curing system; and that the ketone peroxide type catalyst/cobalt napthenate promoter curing systems are not an effective means for curing polyester resins, particularly in a moist low temperature environment.

Therefore, based on previous experience with polyester resin curing systems and to ensure compliance with the requirement for a maximum cure time of 30 minutes to 60 minutes under all conditions of relative humidity, and at any temperature ranging from 40°F to 95°F, a polyester resin curing system composed of benzoyl peroxide catalyst and dimethyl aniline promoter was selected.

The benzoyl peroxide catalyst is an emulsion containing 40% active benzoyl peroxide (BPO) and is designated by the manufacturer (Noury Chemical Corporation) as S0046 Green. This catalyst material has been extensively laboratory tested and was demonstrated to be operational during the 1970 Camp Pendleton test program (Reference 7). This catalyst material is considered the replacement of the previously used On-Fast material system catalyst (U.S. Peroxygen's BZQ-30-128).

The dimethyl aniline promoter used to initiate decomposition of the benzoyl peroxide catalyst during resin polymerization is commercially available from several sources. This material, with viscosity characteristics similar to water, has a freezing point of 36.5°F. The dimethyl aniline is malodorous and can present a health hazard to personnel.

3.2.1.2 Reinforcement and Resin

The mechanical strength of a fiberglass reinforced polyester resin laminate depends not only upon the amount (volume) of reinforcement but also the arrangement of the glass strands in the laminate. A polyester resin laminate made from chopped strand matting has equal strength in all directions due to the random arrangement of glass fibers. When the same amount of glass fibers are specifically oriented such as in a two directional woven roving, then the laminate will exhibit equal and high strengths in two directions. These strengths are higher than is obtained with chopped strand matting. To obtain the maximum effectiveness of a given amount of reinforcement in a polyester resin laminate it is necessary to reduce the amount of voids caused by air entrapment. This may be accomplished by rolling or otherwise working the resin into and throughout the reinforcement.

To maintain reinforcement integrity during field rolling operations and before resin cure, a fabric type reinforcement such as woven roving rather than a non-continuous type reinforcement such as chopped strand matting is desirable. To minimize field rolling effort, a low viscosity resin is desirable because of the relative ease with which a low viscosity resin will penetrate a given reinforcement as compared to a high viscosity resin. This is particularly true when a reinforcement such as woven roving is used.

Based on the inherent strength of this type of reinforcement a composite fiberglass matting composed of 40 oz square yard of woven roving and 18 oz square yard of chopped strand matting chemically bonded to the roving, was selected as the reinforcement material. This reinforcement was used in conjunction with low viscosity resins throughout the materials verification portion of the program.

3.2.1.3 Cleaning Solvent

Although the cleaning solvent is not one of the surfacing materials it is directly related to them and accordingly is considered part of the overall surfacing materials system. A solvent that is satisfactory for cleaning and flushing all fluid dispensing systems requires careful selection. Solvents such as acetone or methyl ethyl ketone, used in the Rapid-Site system or methylene chloride, used in the On-Fast system, perform satisfactorily as regards general cleaning. However, the latter is nonflammable whereas acetone and methyl ethyl ketone are flammable. Therefore, methylene chloride was selected because of its satisfactory performance in the On-Fast system and because of its nonflammable characteristics.

3.2.2 SURFACING MATERIAL VERIFICATION

To verify that the selected surfacing materials would meet the specified curing, mechanical and physical properties, a verification procedure (previously shown in Figure 2) consisting of laboratory and field testing was followed. As can be seen from the flow diagram, and as previously discussed, the resin curing system (benzoyl peroxide catalyst/dimethyl aniline promoter) fiberglass reinforcement (40 oz per square yard woven roving with 18 oz per square yard chemically bonded chopped stranging matting) were preselected as basic items for the materials verification. The fiberglass reinforcement used throughout the verification procedure, designated as MC4008-38-20 was obtained from Hexcell-Traverno Division.

Two low viscosity polyester resin were selected for the materials verification. One resin (designated 26540) was obtained from Hooker Chemical Durez Division and the other (designated 5000 SC19-143) was obtained from PPG Industries. These particular resin manufacturers were chosen because of their previous work in surfacing materials for the Air Force Rapid-Site and U.S. Marine Corps On-Fast systems respectively. According to the manufacturer, resin 26540 is identical (with the exception of being non-promoted) in all respects to resin 26992 previously demonstrated as a satisfactory surfacing resin and will exhibit the same mechanical and physical properties as the 26992 resin.

Resin 5000 SC19-143 was submitted as a low viscosity, high strength resin compatible with woven roving.

3.2.2.1 Laboratory Testing

Laboratory testing was accomplished to verify the material systems performance and mechanical properties. This testing was also used to determine the material formulations used for the field tests and as an initial aid in sizing application equipment fluid dispensing system components and to provide information for the operational usage study (Reference 3). The following laboratory testing was accomplished:

- o Viscosity--Determine effects of temperature on the selected fluids to aid in component sizing.
- o Cup Gel Time Tests--Determine initial catalyst and promoter quantities necessary to formulate resin for a 30 minute to 60 minute maximum cure time over $40^{o}F$ to $95^{o}F$ temperature range.
- o Environment Curing Test--Evaluate the effectiveness of the initial formulations as determined from the cup gel time tests to effect a 30 minute to 60 minute maximum cure time under various conditions of temperature and moisture.
- o Resin Casting Tests--Perform in the event manufacturers data is not available to substantiate the mechanical and physical properties required.
- o Strength Tests--Perform laboratory tests of the selected surfacing materials to initially verify the strengths required for flexure, tension, and shear.

3.2.2.1.1 Viscosity

The viscosity of polyester resins exhibit a marked variation with temperature. Therefore, to properly design the fluid system and select the most effective size of system components, it was considered necessary to determine the resin's viscosity variation with temperature.

The resin viscosities were determined in a manner similar to the "Standard Method of Test for Apparent Viscosity of Plastisols and Organosols at Low Shear Rates by Brookfield Viscometer" ASTM D1824-66. Fluid viscosities were measured over a temperature range of approximately 40°F to 95°F. Viscosities were measured at 2, 4, 10, and 20 rpm as required by the test procedure. Table 2 presents a summary of the seven day viscosity measurements obtained. These results were obtained using a Brookfield (Model RVF) viscometer equipped with a number 2 spindle.

3.2.2.1.2 Cup Gel Time Tests

These tests were performed to initially determine the catalyst/promoter quantities necessary to effect resin cure over the stated 40°F to 95°F temperature range. The tests were conducted using resin previously conditioned at 40°F, room temperature (R. T.), and 95°F.

Three resin samples, 100 grams each, were weighed for each resin, catalyst, and promoter formulation. The catalyst and promoter were added to the previously conditioned resin in increments of percent of resin weight. After mixing, the samples were returned to their respective temperature environments. The start of the elapsed time was considered as the time of mixing the last item in the formulation. Gel time was defined as the time the resin reaches a jello-like consistency. Figures 10 and 11 show the results obtained for the cup gel time tests for 26540 and 5000 SC19-143 resin respectively. As can be seen the gel time characteristics of each resin are similar for a given material temperature and formulation.

3.2.2.1.3 Environment Curing Tests

This test was developed by Boeing as a technique to evaluate the effectiveness of resin curing systems under various conditions of temperature and moisture. The test, used by Boeing for the past five years, is considered an effective means of comparing the degree of cure obtained when using various material formulations under a specific environment. The material formulations shown in Table 3 were based not only on the results of the cup gel time tests but also on observations made during these tests. These observations revealed that although gel time of the two resins was approximately equal for a given material formulation the 5000 SC19-143 resin appeared to reach full cure considerably faster than the 26540 resin, indicating that a higher concentration of catalyst and/or promoter would be required to obtain the same degree of cure for the 26540 resin in the environmental testing.

Table 2: RESIN VISCOSITIES

Fluid Temperature	Spindle RPM	Resin Viscosity (CPS)	
		26540	5000 SC 19-143
40°F	2	640	950
	4	620	940
	10	630	950
	20	636	942
71°F	2	160	250
	4	175	240
	10	180	240
	20	178	236
95°F	2	80	100
	4	75	100
	10	80	96
	20	82	98

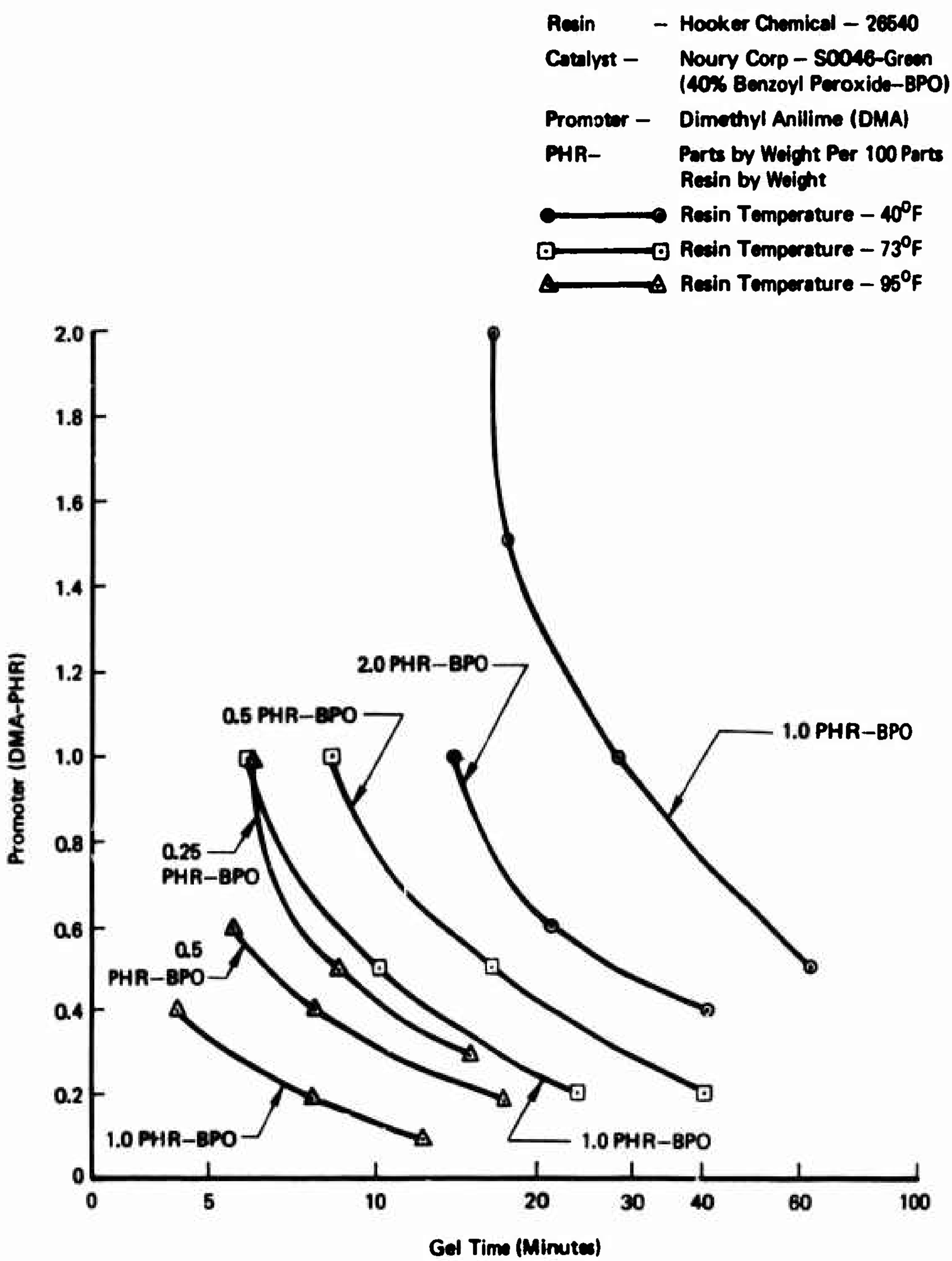


Figure 10: RESIN 26540 GEL TIME

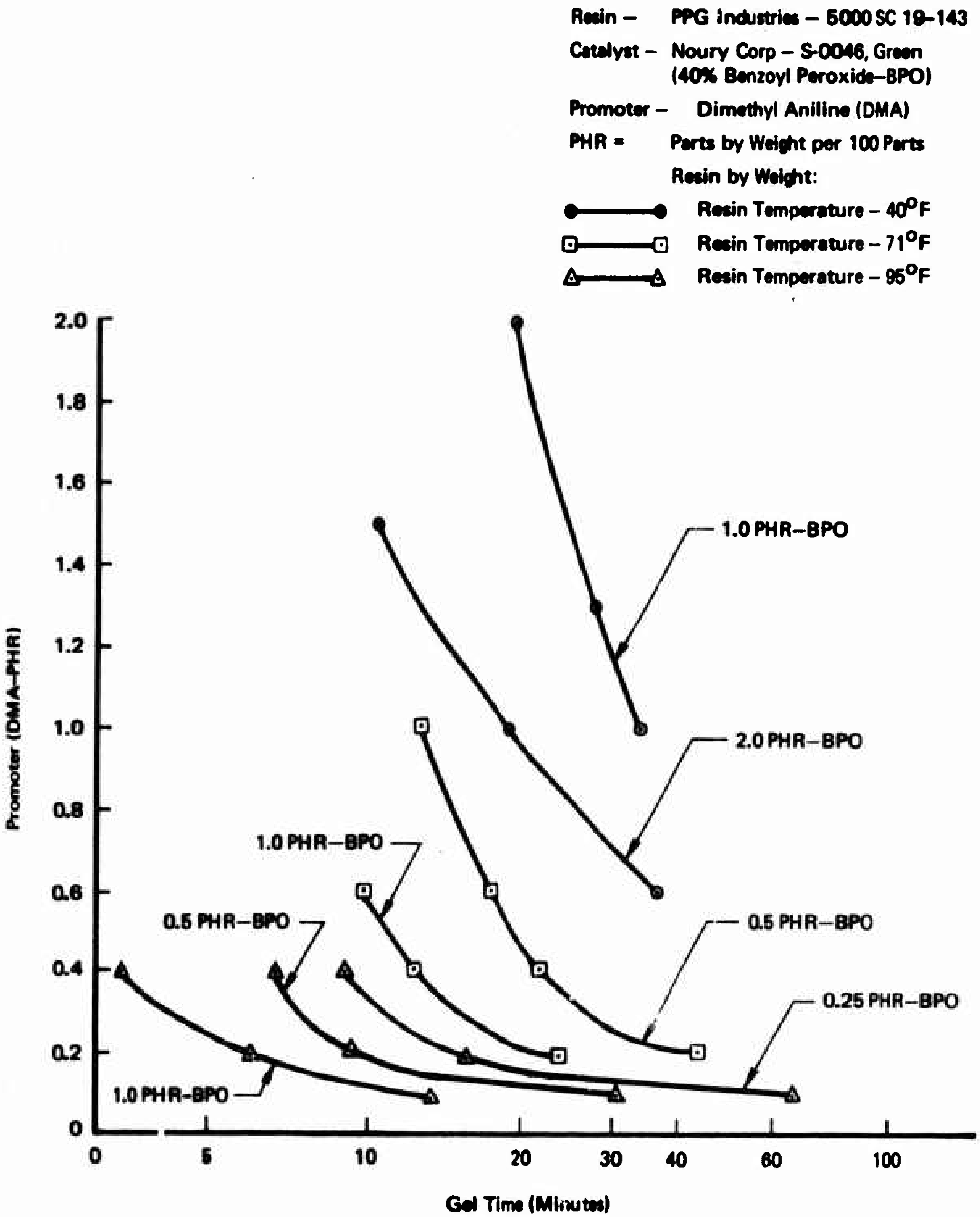


Figure 11: RESIN 5000 SC19-143 GEL TIME

Table 3: SUMMARY – ENVIRONMENT CURING RESULTS

Environment		Resin Formulation		Resin	Shore "D" Reading at Time			
Moisture (Percent)	Temp. (°F)	Catalyst (BPO-PHR)	Promoter (DMA-PHR)		0.5 Hr	1.0 Hr	3.0 Hr	24.0 Hr
0	40	1.5	1.5	26540	24	37	35	40
				5000 SC 19-143	35	33	39	43
	72-73	1.0	0.5	26540	26	35	39	39
				5000 SC 19-143	36	38	38	37
	95	1.0	0.5	26540	21	25	33	35
			0.2	5000 SC 19-143	16	25	27	24
10	40	1.5	1.5	26540	6	20	20	20
				5000 SC 19-143	17	31	38	30
	72–73	1.0	1.0	26540	7	13	15	15
			0.5	5000 SC 19-143	9	20	21	20
	95	1.0	0.5	26540	9	12	12	12
			0.2	5000 SC 19-143	7	11	14	14

Notes: 1. PHR = Parts by Weight per 100 Parts Resin by Weight
2. BPO = Benzoyl Peroxide (1.0 PHR BPO = 2.5 PHR S-0046 Catalyst)
3. DMA = Dimethly Aniline

3.2.2.1.3 Environment Curing Tests

The environment curing tests were conducted as follows: Sand containing 0, and 10 percent moisture by weight was conditioned to 40°F, room temperature (R.T. 71-73°F) and 95°F. Resins were conditioned at 40°F, R.T., and 95°F respectively. 3,000 grams of the conditioned sand was placed in a one gallon cardboard container 6-3/4 inches in diameter and the surface leveled. 100 grams of the conditioned, formulated resin was poured on the surface. The sand and resin was then returned to the respective temperature environment. At intervals of 1/2, 1, 3, and 24 hours after specimen preparation Shore "D" Hardness readings were taken. Three samples were prepared for each condition. The Shore "D" readings shown in Table 3 are the average of 15 readings, five readings obtained from each of the three samples. As can be seen from Table 3, both resins are affected by moisture but by adjusting the quantity of promoter the same degree of cure can be obtained for each resin. In addition, the results indicate that the 26540 resin is more sensitive to a moist environment.

Although considerable variation in Shore "D" readings was obtained, both resins are considered to have cured under the stated environment. The degree of cure ranges from soft, flexible (Shore "D" 11) to a hard, rigid material (Shore "D" 35).

3.2.2.1.4 Resin Casting Tests

The mechanical and physical properties of the cast resins are presented in Table 4. This information was requested from the resin manufacturers. In those instances where the data was not available or the information submitted appeared incomplete, additional testing was accomplished by Boeing. The manufacturers' data submittals are contained in the Appendix.

Both resins exhibited less than the required 6.5% minimum value for tensile elongation. Contact with responsible personnel of Hooker Chemical and PPG Industries respectively indicate that this would not be detrimental to satisfactory field performance of the surfacing materials. The 26540 resin, has, as previously stated, the same mechanical and physical properties as the 26992 resin which has been demonstrated as satisfactory in the Air Force's Rapid-Site system. The 5000 SC19-143 resin, submitted for low viscosity, high strength characteristics attains these properties, according to the manufacturer, at the expense of flexibility. In development of the U.S. Marine Corps' On-Fast system, flexibility was considered important because of the relatively low glass content (approximately 20%) compared to 40% in the present Advanced Surfacing Systems. Since the low glass content of the On-Fast System precluded high strength characteristics, the property of high elongation before failure was thought necessary. This would allow the surfacing to accommodate large deflections when failure of the subgrade occurred. The requirement for high elongation led to the development of resin RS58-831 (PPG Industries designation). Based on satisfactory field performance it was initially selected for the On-Fast material system and a proposed military specification (Reference 8) was developed that defined the mechanical and physical properties of this particular resin.

Table 4: MECHANICAL AND PHYSICAL PROPERTIES

Property	Federal Standard Test Method	Required	Resin 26540	Resin 5000 SC 19-143
Tensile Elongation	406-1011	6.5% (Minimum)	1.82%	1.10%
Heat Distortion °C 264 psi	406-2011	55°C (Minimum)	66.5°C	97°C
Impact Strength IZOD Notch	406-1071	0.1 Ft-Lbs/ Inch of Notch (Minimum)	(0.493)	0.374
Abrasion Resistance C-17 Wheel	406-1091	Milligrams of Loss (Maximum)		
100 Cycles		15	(6)	(4)
500 Cycles		75	(63)	(32)
1,000 Cycles		85	106	(73)
5,000 Cycles		- -	422	(485)
10,000 Cycles		- -	770	(868)
Absorption (24-Hour Immersion)	406-7031	% Weight Increase (Maximum)		
Water		0.30	(0.109)	0.16
Hydraulic Fluid (MIL-H-5606)		0.20	(0.031)	0.20
Isopropyl Alcohl (TT-I-735)		0.20	(0.032)	(0.003)

Note: ( ) Indicates Contractor Accomplished

3.2.2.1.4 Resin Casting Tests (Cont)

Further contact with knowledgeable representatives of Hooker Chemical, PPG Industries and Dow Chemical, inspection of numerous resin manufacturers data sheets, and research of plastic handbooks has resulted in the following summary of the effect that flexibility, as indicated by resin tensile elongation, has on the resultant mechanical and physical properties of both the cast resin and resin fiberglass laminate. In general, as the tensile elongation of the resin increases from less than 1% to approximately 2-1/2 - 3%, compression and shear strength decreases while flexure and tensile strength increases. As tensile elongation increases beyond approximately 3-4% total physical properties (compression, shear, flexure, and tension) decrease.

As regards fatigue properties of reinforced polyester resins, there appears to be no direct method of equating percent tensile elongation to fatigue life. It has been stated that better fatigue test results are obtained with the more rigid resins. Also, that reinforced polyesters may be loaded to approximately 50% of ultimate strength for short term service (10^4 - 10^5 cycles) whereas for long term service (10^7 - 10^8 cycles) the loading must be reduced to approximately 25% of ultimate strength.

In addition to the above, available information indicates that the degree of resin flexibility generally influences the properties listed below as follows.

- o Abrasion Resistance--Increasing flexibility results in decreasing resistance to abrasion
- o Water Absorption--Increasing flexibility results in increasing water absorption
- o Chemical and Weather Resistance--Increasing flexibility results in decreasing resistance to chemicals and weathering
- o Reactivity (Cure Rate)--Increasing flexibility decreases rate of cure and increases sensitivity to temperature change
- o Environmental Temperature Resistance--Increasing flexibility increases sensitivity. At low temperatures flexible resins become very brittle while at elevated temperatures they become extremely soft and lose almost all their properties
- o Impact Strength--Increasing flexibility increases impact strength

As can be seen from Table 4, resin 5000 SC19-143 meets all other test requirements. Results for resin 26540 show less than the required resistance to abrasion at 1,000 cycles. However, it should be noted that although the 5000 SC19-143 resin meets the requirements as regards milligrams of weight lost for the number of cycles specified, it appears that it wears at a faster rate than the 26540 resin as evidenced (Table 4) by a comparison of the milligrams of weight lost for each resin at 5,000 and 10,000 cycles respectively.

3.2.2.1.5 Strength Tests

Prior to performing the field applied surfacing material tests, the selected surfacing materials were used to prepare 12 inch x 12 inch panels. These panels were used to obtain strength data to indicate basic strength that could be achieved under laboratory conditions. In addition they were used to determine the amount of rolling required for the field applied materials. The panels were fabricated at a planned weight of 2 pounds per square foot with resin content approximately 60% by weight. Three panels were fabricated for each of the two resins under consideration. Each set of three panels were constructed as follows:

- One panel with no rolling
- One panel with a single pass of a roller
- One panel with multiple passes of a roller

Table 5 presents a summary of the results obtained from the various strength tests. In one instance the required strength was not obtained; occurring with shear specimens cut from the unrolled 26540 resin panel. Based on the results obtained from the laboratory strength tests of the two resins it was decided to prepare both rolled and unrolled field applied surfacing and test specimens of each condition.

3.2.2.2 Field Tests

Field applied surfacing sections were fabricated from both the 26540 and 5000 SC19-143 resin. Materials were applied over a cleared, level area (approximately 12 feet by 12 feet) having adequate subgrade strength to allow rolling. After the surfacing materials had obtained cure, 10 randomly selected panels of sufficient size to obtain the required test specimens and one 2-foot x 2-foot panel were cut from the completed surfacing.

In preparation for the field tests, since it was planned to use the manual spray unit (MSU), flow rates of the 26540 and 5000 SC19-143 resin were determined using the MSU equipped with 20 feet of resin delivery hose and resin outputs were determined at selected engine rpm settings.

In conjunction with the resin flow rate determinations, the capability to field apply low temperature resin was verified. Both resins 26540 and 5000 SC19-143 were sprayed at a material temperature of 39°F as read on the MSU resin line thermometer. Resin outputs were consistent with those previously determined and no resin fan angle degradation was observed during the low temperature resin spraying tests.

Table 5: SUMMARY – LABORATORY STRENGTH TESTS

Resin	Weight (Lbs Per Sq. Ft.)	Percent Resin (By Wt.)	Flexure (PSI)	Tension (PSI)	Shear (PSI)	Remarks
26540	1.98	62.4	49,949	22,098	13,365	Rolled 4 Times
	1.96	61.9	46,271	21,959	13,002	Rolled 1 Time
	1.99	61.5	43,015	20,632	11,438	Not Rolled
5000 SC 19-143	2.01	65.9	36,136	18,215	13,534	Rolled 4 Times
	2.03	62.8	37.514	20,282	13,636	Rolled 1 Time
	2.03	63.7	38,933	17,301	14,203	Not Rolled

3.2.2.2.1 Field Applied Surfacing---Resin 26540

Prior to applying the surfacing materials a small 12 inch x 12 inch panel (approximately 2 lbs/sq ft) was fabricated over the selected subgrade to verify the planned resin formulation. This panel was fabricated by pouring and single pass rolling. The resin was formulated with 1.0 PHR active benzoyl peroxide. (2.5 PHR catalyst emulsion) and 0.5 PHR dimethyl aniline promoter. Materials and environment temperatures ranged from 65°F to 68°F. Resin gel time was approximately 20 minutes and was considered satisfactory for the surfacing sections.

Both the rolled (single pass) and unrolled sections of the surfacing sections were fabricated using the MSU to dispense the liquid materials. After cure, ten randomly selected samples were cut from each of the rolled and unrolled sections. From each sample, one specimen each for flexure, tension, and shear was obtained and tested per ASTM Standard test methods D-790-66, D-638-68, and D-732-42 respectively. Average values and deviations were computed from the following formulas:

$$\bar{x} = \frac{1}{10} \sum_{i=1}^{10} x_i$$

$$S = \sqrt{\frac{1}{9} \sum_{i=1}^{10} (x_i - \bar{x})^2}$$

$\bar{x} = \bar{x}_f, \bar{x}_t$, and $\bar{x}_s$

S = Deviation

In addition to determining the strengths and deviations of the rolled and unrolled sections, five specimens each for flexure, tension and shear were obtained from the 12 inch x 12 inch panel and tested as described above. After strength testing, the resin content of representative specimens was determined by resin burnout per ASTM D-2584-58, "Standard Method of Test for Ignition Loss of Cured Reinforced Resins." Table 6 presents a summary of the strength test results. A 2 foot x 2 foot panel was obtained from the surfacing fabricated by applying the resin with the manual spray unit and rolled with a single pass of a roller. Although the field applied 26540 resin surfacing did not meet the stated strength requirement as regards shear, the 2-foot by 2-foot panel was submitted for consideration by NCEL.

Table 6: SUMMARY – STRENGTH TEST RESULTS – RESIN 26540

Surfacing Section	Resin Content (% By Weight)	Strengths (psi)			Deviations (psi)		
		Flexure	Tension	Shear	Flexure	Tension	Shear
Rolled	62.5	31,870	17,124	9,411	5,813	2,689	1,170
Unrolled	63.7	22,040	15,911	8,431	7,806	3,508	1,323
12" x 12" Panel	56.9	38,154	20,571	12,113	5,586	1,860	1,177

3.2.2.2.2 Field Applied Surfacing---Resin 5000 SC 19-43

Based on the strength tests of the field applied 26540 resin it was decided to prepare rolled (single pass) surfacing sections from the 5000 SC19-143 resin by using both the manual spray unit and hand application (pouring) to dispense the liquid materials. Resin was formulated with 1.0 PHR benzoyl peroxide catalyst and 0.2 PHR dimethyl aniline promoter. Materials and environment temperatures ranged from 78^{o}F to 85^{o}F. A satisfactory resin gel time of approximately 17 minutes was obtained.

After cure 10 random samples were obtained from each surfacing section and flexure, tension, and shear specimens were obtained and tested as previously described. Table 7 presents a summary of these strength test results. A 2-foot by 2-foot panel was obtained from the surfacing fabricated by pouring resin and rolled with a single pass of a roller and submitted to NCEL.

3.2.2.2.3 Field Applied Surfacing---Second Series

Based upon test data received from NCEL a second series of surfacing sections were constructed. The surfacing sections, fabricated over soil at an approximate weight of 2 lbs/sq ft were composed of approximately 60% resin and 40% fiberglass by weight. Sections were constructed from both the 26540 and 5000 SC19-143 resin. All sections were prepared by pouring resin and rolled with two passes of a roller. All resin formulations were 1.0 PHR active benzoyl peroxide catalyst (2.5 PHR catalyst emulsion) and 0.2 PHR dimethyl aniline promoter. Resin gel time was approximately 20-30 minutes. After cure 10 random samples were obtained from each surfacing section. Flexure, tension, and shear specimens were obtained and tested as previously described. A summary of the results obtained has previously been shown in Table 1. Additionally, 2-foot by 2-foot panels were obtained from the surfacing sections and submitted to NCEL.

3.3 Operational Usage Study

The operational usage study was based on a review of both the Marine Corps On-Fast and Air Forces Rapid-Site surfacing systems as well as the operational and surfacing requirements set forth in NCEL Contract N62399-71-C-0016 for the Advanced Surfacing Systems. The overall objective of the study was to define the best practical surfacing system and procedures and to identify any factors that affect system usage.

The study was based on application equipment consisting of a high rate self-propelled surfacer capable of applying surfacing at a rate of 10,000 square feet per hour and a low rate trailer mounted unit employing manual application techniques with a surfacing capability of 2,000 square feet per hour. The high rate system configuration includes a truck mounted liquid and fiberglass dispensing system which simultaneously applies two strips of fiberglass and deposits the proper amount of resin on to the fiberglass. This is followed with a separate item of equipment to roll the wet surface to promote thorough saturation of the mat with resin. The low rate system configuration includes a trailer mounted liquid dispensing system which is used to apply resin from a hand held spray bar to a strip of fiberglass which has been manually emplaced. The wet fiberglass is then rolled manually.

Table 7: SUMMARY – STRENGTH TEST RESULTS – RESIN 5000 SC 19-143

Surfacing Section	Resin Content (% By Weight)	Strengths (psi)			Deviations (psi)		
		Flexure	Tension	Shear	Flexure	Tension	Shear
Poured	60.1	41,789	16,892	13,890	7,778	2,737	1,202
Sprayed	62.3	28,779	12,978	10,249	3,076	1,812	1,002

3.3 OPERATIONAL USAGE STUDY (Cont)

The surfacing materials used for the study are those previously discussed (Section 3.2) and consists of a composite fiberglass reinforcement composed of a bottom layer of woven roving with an overlay of chopped strand mat in conjunction with a low viscosity resin and utilizing a benzoyl peroxide/dimethyl aniline curing system.

3.3.1 OPERATIONAL USAGE

Prior to accomplishing the detailed system analysis of surfacing operations conforming to the specified 5 and 6 hour continuous surfacing rates for the high and low rate equipment systems respectively, operational usage of the system was considered for varying applications. This portion of the study was also necessary to define the equipment systems required, methods of surfacing construction to be used, transportation, storage and handling of equipment and materials, and methods of materials dispensing required for the detailed system analysis. Additionally, effects of the surfacing materials on the ecology were considered.

3.3.1.1 System Applications

Usage of the advanced surfacing systems was analyzed based on the applications listed in Table 8. Since the various surfaced areas will vary widely in size with specific applications, no dimensions are given. For such applications as airfield surfacing the typical area will be large, essentially level, and must withstand heavy loads. Such an area is ideally suited to the high rate surfacer. For erosion control, water containment or waterproofing applications, loading will generally be low and widely varying conditions of terrain slope and roughness, soil strength, and area shape will be encountered. Some of these, such as small or irregularly shaped areas, surfacing over uneven terrain, or surfacing areas accessible only by helicopter or current STOL aircraft, can be done economically only with the low rate surfacing equipment.

Figure 12 provides an estimate of the effect of surface area on the relative efficiency of the high and low rate systems. The curves are based upon constant peak surfacing rates with a fixed time required to prepare the equipment for operation and a fixed time to prepare the equipment for transportation. Non-productive travel time of 4 hours was assumed for each crew. Materials pre-positioning time was included for areas larger than 7,000 square feet when using the low rate unit and areas larger than 16,000 square feet when using the high rate unit. Materials pre-positioning for smaller areas can be accomplished concurrently with equipment preparation. The relationship shown in Figure 12 indicates a break even point of approximately 12,000 square feet above which the high rate unit appears more efficient.

When specific wheel loads and subgrade conditions are known, the procedures for computing site thickness contained in references 9 and 10 are recommended.

For lightly loaded or non-traffic areas, experience with the On-Fast system indicates that a total surfacing weight of less than 1.0 psf is adequate. Based on that experience .2 psf reinforcement with sufficient resin for saturation is believed more cost effective. A somewhat greater ratio of resin to glass may be desirable when using the lightweight reinforcement, particularly where waterproofing is necessary.

Table 8: SURFACING APPLICATIONS

Usage	Equipment Required on Typical Area
1. Airfield Ramp Parking	High rate for large areas; Low rate for joints, fillets and irregular areas.
2. Vehicle Operation	Either unit depending on size
3. Material Storage	Either unit depending on size
4. Vehicle Parking	Either unit depending on size
5. Helicopter Pads	Low rate for single pads; High rate for multiple pads
6. Floors	Low Rate
7. Sidewalks	Low Rate
8. Water Containment (Includes ditches, dike lining and basins.) [1]	Low Rate
9. Waterproofing (Includes roofing, revetment covers, area waterproofing, bunker covers and similar uses.)	Low Rate

[1] Because of potential toxicity, water which has been in contact with the surfacing material must be limited to industrial use only and not for human consumption.

Low Rate System Formula

for $A < 7000$ Sq Ft

$$R = \frac{A}{33.6\ MH + (.0025A)\ MH.}$$

for $A > 7000$ Sq Ft

$$R = \frac{A}{33.6\ MH + .0025A\ MH + (A-7000)\ .00071\ MH}$$

High Rate System Formula

for $A < 16{,}000$ Sq Ft

$$R = \frac{A}{52.5\ MH + (.0009A)\ MH}$$

for $A > 16{,}000$ Sq Ft

$$R = \frac{A}{52.5\ MH + .0009A\ MH + (A-16{,}000)\ .00053\ MH}$$

R = Surfacing Rate (Sq Ft/MH)
A = Surfaced Area (Sq Ft)
MH = Manhours

33.6 MH Term Includes
13.6 MH for Preparation
& Cleanup + 20 MH Travel.

$$.0025 = \frac{5\ MH}{2000\ Sq\ Ft}$$

$$.00071 = \frac{{}^{*}(1.71\ Hr)(5\ Men)}{12{,}000\ Sq\ Ft}$$

* Ref Figure 41:

52.5 MH Includes 16.5 MH for
Preparation & Cleanup +
36 MH Travel.

$$.0009 = \frac{9\ MH}{10{,}000\ Sq.\ Ft.}$$

$$.00053 = \frac{{}^{**}(2.93\ HR)\ (9\ MEN)}{50{,}000\ Sq\ Ft}$$

** Ref. Figure 22

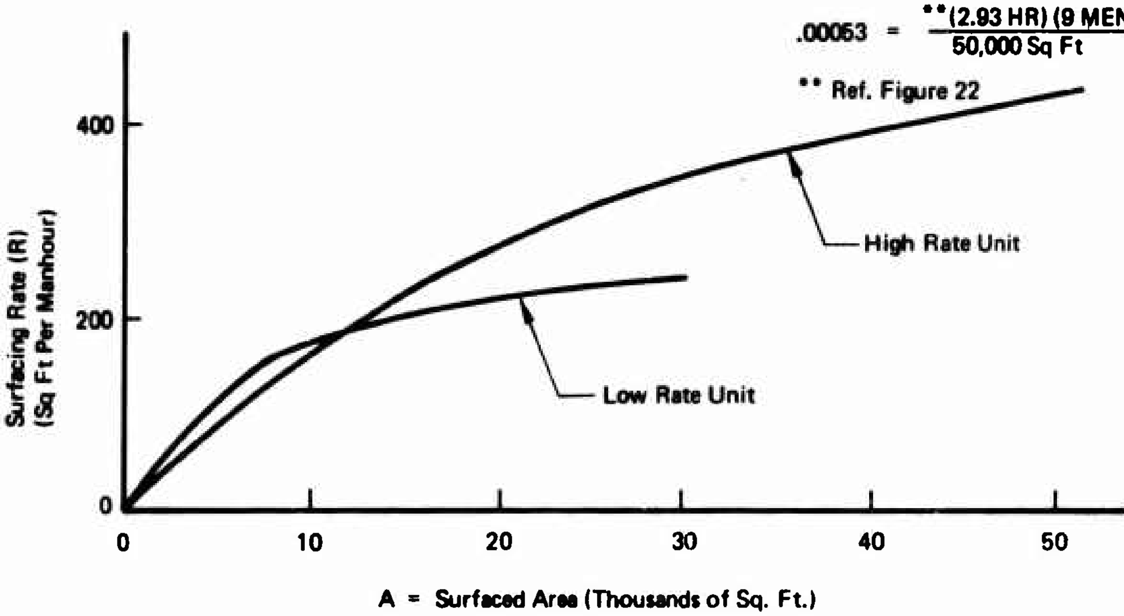


Figure 12: EFFECT OF SURFACE AREA ON MANPOWER EFFICIENCY

3.3.1.1 System Applications (Cont)

Where loading conditions permit, the use of lightweight reinforcement is also believed to offer the advantage of being easier to saturate on steep slopes because there is less resin available to run off and thinner reinforcement should require less time for wetout.

There are some uncertainties however, regarding operations utiliz g lighter weight reinforcement and applications on slopes. Questionable area that can best be investigated through follow-on testing include adequacy of reinforcement of approximately .2 psf, the best resin to glass ratio, and the desirability of rolling such applications.

3.3.1.2 Construction Methods

Field construction methods for fabricating end to end and side to side joints, edge anchoring, and expansion joints are illustrated in Figures 13 through 16. The staggered end to end joints shown in Figure 13 are more convenient than aligned ends when using the high rate system because with staggered ends the resin spray can be initiated simultaneously in both spraybars and left on throughout the surfacing pass, then simultaneously terminated. In order to align the ends a short section of the leading fiberglass roll would have to be sprayed before securing both ends and completing the pass. This would involve a slight time and convenience penalty. Whichever method is employed, reinforcement roll lengths should be as uniform as is practical to avoid unncessary trimming or large overlaps. For normal side to side laps where 1, 2, 3, or 4 layers are applied, Figure 14 is applicable. Experience during field and laboratory testing indicates a minimum nominal lap width of 6 inches is required to maintain the strength of the surface across a joint, thus establishing the single layer arrangements. For the two layer case, the arrangement shown in Figure 14 is considered more desirable than a 50% lap of each layer when using the high rate equipment because:

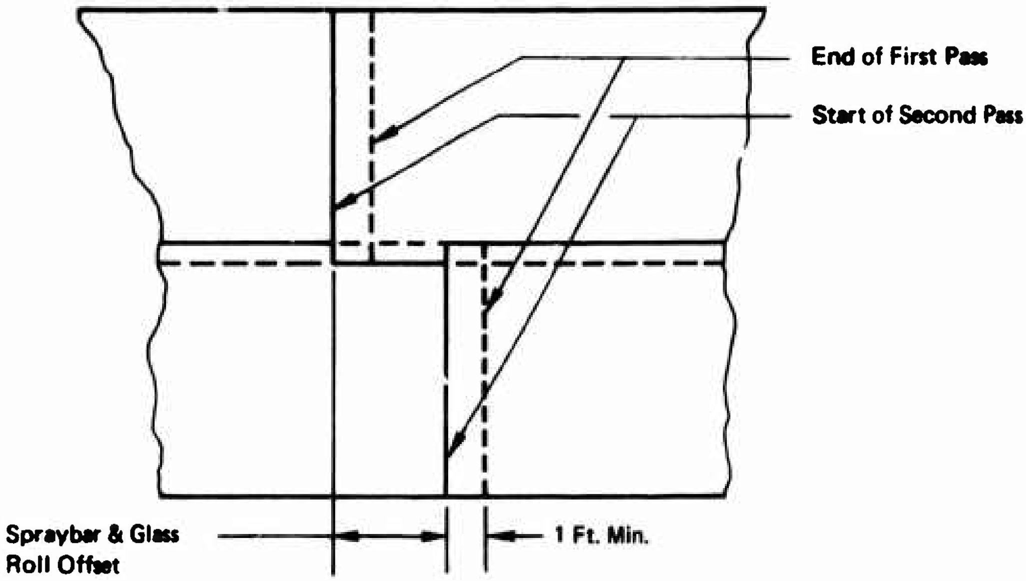
1) It is assumed that bonding to a cured surface will require prewetting the joint area and a smaller lap is easier to wet because a smaller simpler adapter on the spraybar can be utilized.

2) Vehicle eccentric loading is lower.

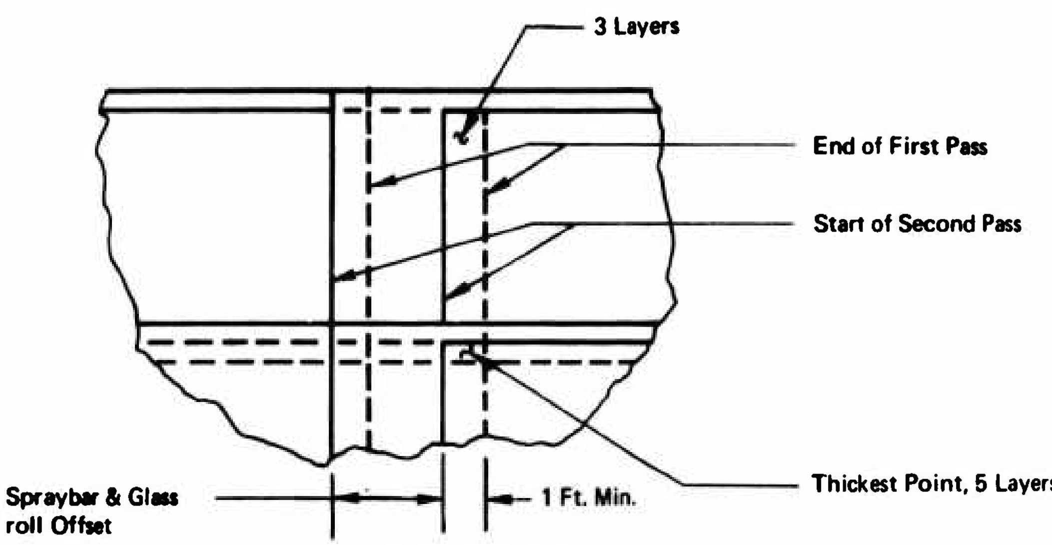
3) Guidance during glass application is easier to maintain with a narrower lap width.

During surfacing with the low rate equipment a lap of 50% plus 6 inches is believed to be more practical because when applying the second layer with a full lap, as in Figure 14, access would be limited to one edge of the mat because of the wet bottom layer. Maintaining proper alignment would probably be difficult under these conditions.

For the three layer surface, a nominal lap width of 2/3 the roll width plus 2 inches will provide a 6-inch longitudinal overlap of the adjacent edges of the bottom and top layers (first and fourth respectively). Though this may require a large prewet area, it allows continuous operation without the need to change the fiberglass arrangement on the equipment.



SINGLE LAYER SURFACE

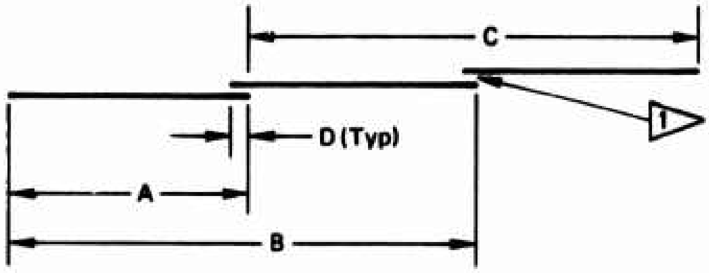


DOUBLE LAYER SURFACE

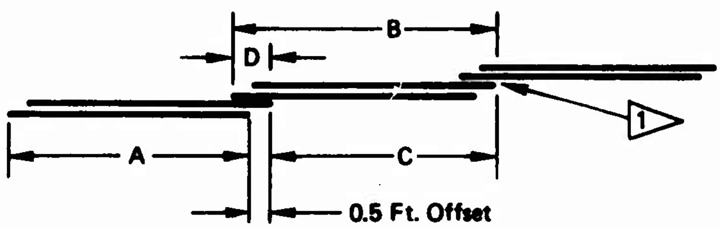
Notes:

1. Staggered ends remaining at the end of a strip may be trimmed or covered with an edging strip.
2. Surface may, if desired, be started with the ends aligned, however, fiberglass roll length variation may produce staggered runout points.
3. Three and four layer surfaces may be applied similarly.

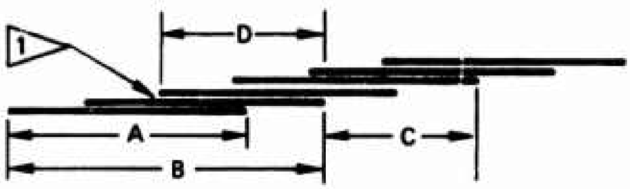
Figure 13: END TO END LAP CONSTRUCTION WITH HIGH RATE SURFACER



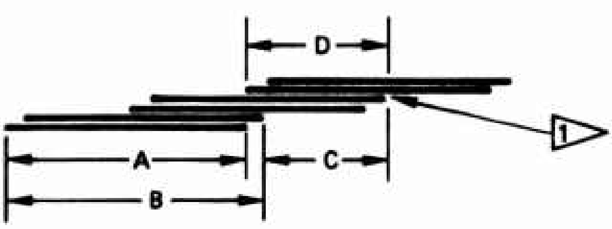
Single Layer



Double Layer



Triple Layer

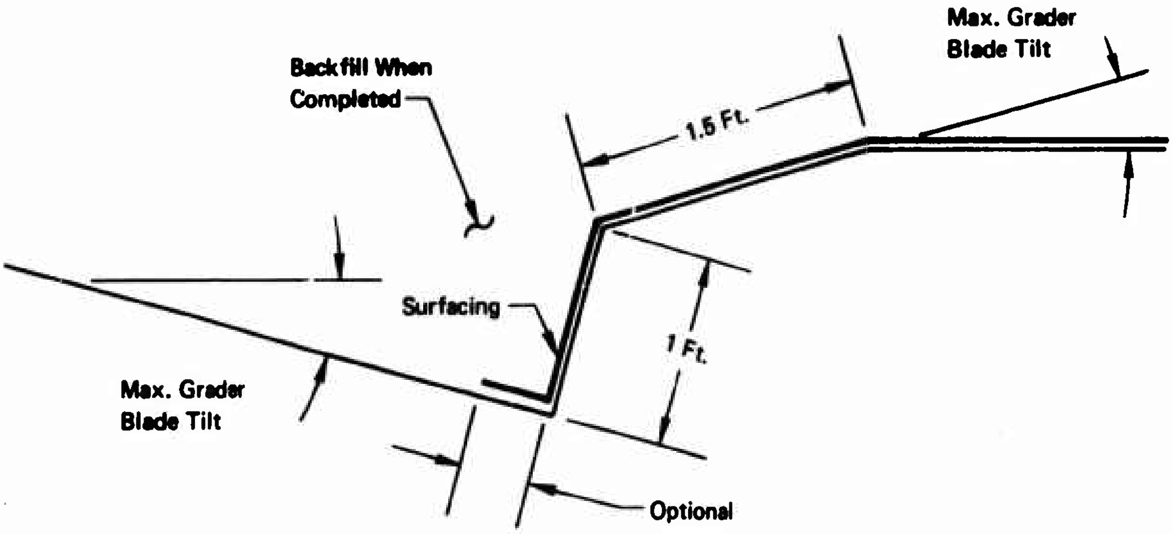


Four Layer

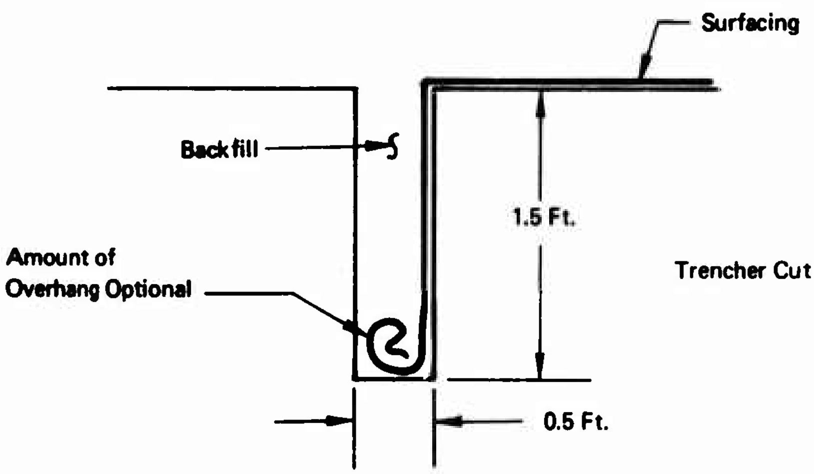
Dimensions in Feet			
Roll Width A	Pass Width B	Advance C	Lap Width D 1
5.0	9.5	9.0	0.5
6.5	12.5	12.0	0.5
8.0	15.5	15.0	0.5
5.0	5.5	4.5	1.0
6.5	7.0	6.0	1.0
8.0	8.5	7.5	1.0
5.0	6.5	3.0	3.5
6.5	8.5	4.0	4.5
8.0	10.5	5.0	5.5
5.0	5.5	2.5	3.0
6.5	7.0	3.25	3.75
8.0	8.5	4.0	4.5

1 Overlap Area Must be Free of Loose Dirt and Must be Resin Wet.

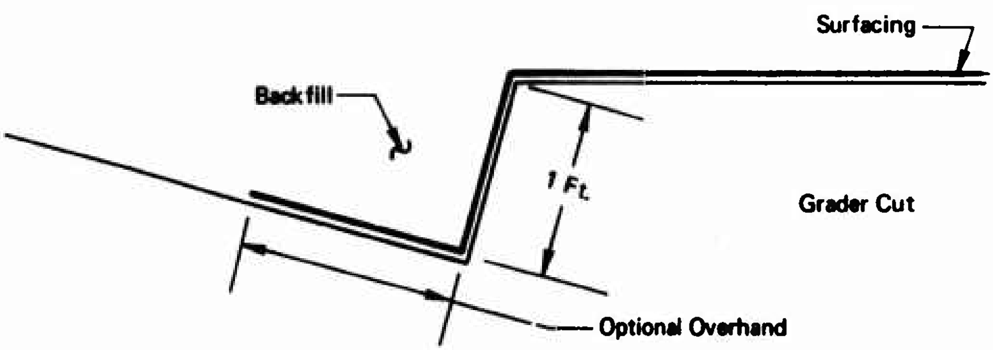
Figure 14: LAP JOINT CONSTRUCTION



Method 1 – Edging Subject to Traffic

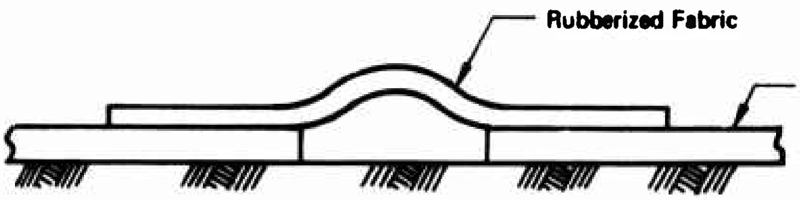


Method 2 – Edging Not Subject to Traffic

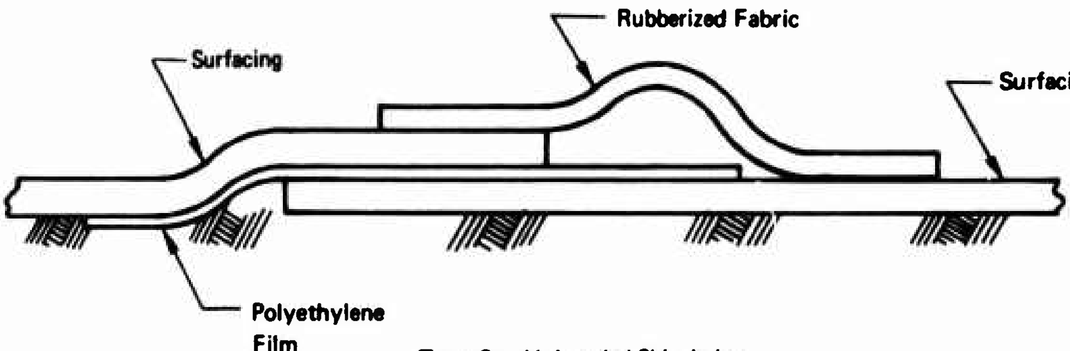


Method 3 – Edging Not Subject to Traffic

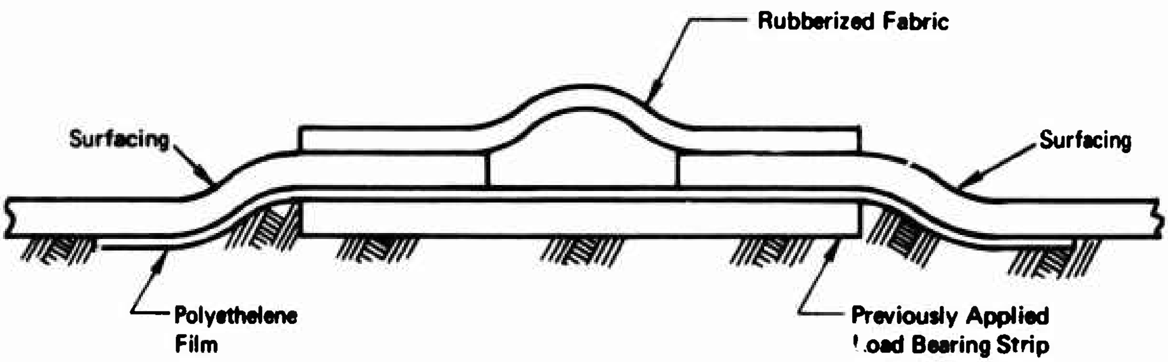
Figure 15 : EDGING CONSTRUCTION



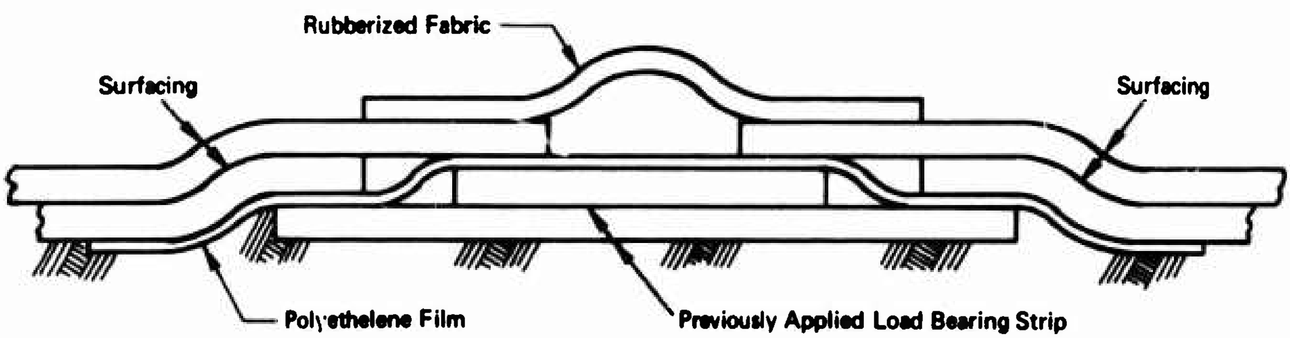
Type 1 – Non Load Bearing Expansion Joint



Type 2 – Unbonded Shingle Lap



Type 3 – Load Bearing Single Layer Expansion Joint



Type 4 – Load Bearing Multi-Layer Expansion Joint

Figure 16: POSSIBLE EXPANSION JOINT CONSTRUCTION

3.3.1.2 Construction Methods (Cont)

For the 4-layer surface, the same glass arrangement on the high rate equipment may be used as for the 2-layer surface. Using an overlap on each pass of 50% plus 6 inches a possible local buildup of up to 8 layers is avoided as could occur if the layers were stacked directly. During normal operations it is expected that the surfacing would proceed on a continuing basis and that the previously applied surface would not have cured before the next layer is applied. This would preclude the need for prewetting the lap area. During operations over soft soil where the surfacing equipment must travel on previously cured surfacing, or when other reasons prevent uncured lap joints, prewetting the entire joint area should be possible for the different overlap arrangements.

Since the combination of cured lap joints and 3 or 4 layer surfacing is not frequently expected however, the prewetting in these cases may be accomplished with a separate pass depositing a light resin coat through one spraybar without dispensing fiberglass.

In nearly all surfacing applications, edge anchoring will be required to prevent wheel or wind pickup. Several edge configurations have been field tested. Where the edge must withstand repeated traffic, a configuration with a beveled or rounded edge as shown in Method 1, Figure 15 is recommended. This has been tested in helipad construction at Camp Pendleton (Reference 7) and appears to withstand traffic better than a 90^{o} fold. This method also reduces crumbling in non-cohesive soils. Where edge traffic is not anticipated and crumbling is not a problem, a sharp edge or trench should be adequate and could reduce the disturbance of surrounding soil or vegetation. Since testing relative to edge type evaluation has been limited, continued evaluation of edging methods during field use is recommended.

In constructing large surface areas, thermal expansion and contraction must be considered. Past experience is very limited but indicates that surfaces longer than approximately 150 feet in length may require expansion joints. Three different types of expansion joints have been field tested, none of which proved successful. These are described in detail in Reference 7. A fiberglass "U" section failed under wheel traffic during testing and a cast section of flexible resin failed to relieve the expansion. An unbonded shingle lap successfully dissipated the expansion and held up under test traffic but subsequently failed due to either wind or wheel action lifting the loose end. The most promising methods conceived to date are shown in Figure 16. Using a rubber or rubberized fabric strip bonded to the ends of the joint, seals the surface against water and ties the ends together to prevent pickup but still allows flexing. The Type 1 joint is the simplest. However, other methods although more difficult to fabricate provide better load support across the joint. Additional investigation is needed in order to develop successful expansion joints and to determine under what conditions expansion joints are needed.

3.3.1.3 Transportation, Storage and Handling

In general materials shipped to adverse weather or combat areas should have Level A Military Pack in accordance with MIL-STD-129. All steel drums (solvent, promoter, catalyst) should be protected with a paint system that will withstand the corrosive effects of weather. Weatherproof, non-corrosive, non-degradable labels should be used for absolute identification of contents.

3.3.1.3 Transportation, Storage and Handling (Cont)

- Fiberglass--Packaged fiberglass does not present any known hazards or unique requirements during transportation and handling and will survive in good condition any storage conditions that the packaging will withstand. For long term storage, the packages should be indoors or covered to keep off rain or snow. Handling the material during use, particularly when cutting, may cause itching or irritation of the skin. Long sleeved clothing changed daily and good personal hygiene are all that is normally required.

  Previous fiberglass shipments to RVN were in accordance with MIL-STD-129 Level C Pack. This was found inadequate in protecting the thin polyethylene inner liner against abrasion and subsequent rupture during handling and shipping. Fiberglass in commercial pack would require SEAVAN shipment with door-to-door delivery. Fiberglass destined for adverse weather or combat areas should use packaging employing an inner liner, heavy cushioning and a moistureproof multiwall barrier to prevent abrasion and rupture of the liner.

- Resin--Transportation and handling of polyester resin using normal good practice should present no problems. However, certain precautions should be observed. Any containers showing evidence of leakage should not be transported in closed compartments. Ventilation of ship holds or railroad cars transporting resin is recommended. Although vapors are not highly toxic and the effects are usually transient, in high concentration they may cause headaches and dizziness; therefore entering closed compartments where the characteristic odor is strong should be avoided. The styrene in the resin is considered dangerous to the eyes and irritating to the skin. Water and soap should be available for washing the skin along with a supply of water for flushing the eyes in case of direct contact with resin. Prolonged or extensive skin contact should be avoided. The material is rated as moderately flammable Class III by the National Bureau of Underwriters, and should be treated accordingly.

  Resin should be stored in a cool, well ventilated area. Recommended storage temperature is below 77°F for maximum lift. Though higher temperatures do not have any immediate effect, the shelf life of the resin is a function of time and temperature with the degradation taking the form of increased viscosity. Exact life is at present not well defined and additional data should be collected on material used under field conditions. When using stored resin and other system materials, a good practice would be to use the oldest material first. Material to be stored outside for more than a few days should be protected from the sun when temperatures will exceed approximately 80°F. Exposure to sunlight will cause resin to cure, therefore, open containers should not be left outside.

  The plywood resin containers such as previously used in the On-Fast program and planned for the advanced surfacing system are designed for forklift handling and normal good handling practices are required. The On-Fast containers experienced resin leakage by way of the threads on the bolts used to secure the resin outlet connector fitting. This type of fitting was subsequently modified to provide a more positive seal and was installed in the plywood resin containers used in the Advanced Surfacing Systems.

3.3.1.3 Transportation, Storage and Handling (Cont)

- Catalyst--The catalyst, a 40% active benzoyl peroxide in emulsion, packaged in lined standard 55 gallon containers, does not present any unique handling requirements. Spills of the material should be promptly cleaned up because spilled material that has dried out has a higher than normal proportion of benzoyl peroxide and is an extreme fire hazard. During preparation for use the material may require mixing. This should be limited to mild paddling action. The use of high speed mixing equipment could cause a breakdown of the emulsion and cause difficulty in pumping.

  Catalyst should be stored in a cool well ventilated area away from the promoter, at a recommended temperature of 65 to 85°F. The catalyst temperature must not be permitted to exceed 100°F. Should this occur, a degradation of the activity will result. All physiological effects have not been determined. However, the material is irritating to the eyes, mucous membranes and skin. Prolonged or extensive skin contact should be avoided. Water and soap should be available when catalyst is being handled.

- Promoter--The promoter, dimethyl aniline, packaged in standard 30 gallon containers, does not present any unique handling requirements. Dimethyl aniline is however the most toxic of the materials used. The material is readily absorbed through the skin, may cause serious eye damage if splashed in the eyes, may be fatal if swallowed and breathing the vapors is hazardous. Rubber gloves and a face mask should be worn when direct exposure such as opening filled lines is expected. Water for flushing exposed skin and the eyes should be available at all times.

  Promoter should be stored in an area away from the catalyst. No unique storage requirements are known. The material freezes at 36.5°F. However, aside from limiting usage, freezing has no apparent effect. It is flammable when heated or sprayed and the vapors resulting from a fire or heating are highly toxic.

- Solvent--Methylene chloride as packaged in standard 55 gallon containers does not present any unique transportation or handling requirements. The solvent is not highly toxic; however, it is dangerous to the eyes and prolonged contact with the skin or breathing of a high concentration of vapors should be avoided. Though not flammable under normal conditions, the material breaks down under high temperature to form toxic and corrosive gases. The material will attack most paints and care should be exercised accordingly. Because of its volatility, care is required to prevent frostbite when the solvent is used in cold weather.

  The solvent should be stored in an area where the temperature will not exceed 120°F. If this temperature may be exceeded, the drums should have the bungs loosened to relieve any vapor pressure buildup. Material stored outside should be protected from direct sunlight if temperatures will exceed approximately 90°F.

3.3.1.3 Transportation, Storage and Handling (Cont)

All high rate equipment required to dispense and roll the surfacing can be carried on the respective vehicles which when arranged for transport may be driven, transported by surface or transported by air using a C130 or larger aircraft. Although all specific requirements had not been developed at the time of this study, the surfacing equipment did not present any unique requirements for handling equipment now in service. Long term active storage should be inside and generally in accordance with T. O. 36-1-5 (Reference 11) which specifies exercise at 30 day intervals.

The low rate equipment trailer is capable of being towed or transported by surface or air using a C130 or larger aircraft. With the exception of not being self-propelled, the low rate dispensing equipment is similar to the high rate equipment and the same comments regarding handling and storage apply.

3.3.1.4 Material Dispensing

The application of surfacing under all specified environmental conditions, requires the addition of catalyst and promoter to the resin in the amounts required to effect a cure in less than one hour after it is applied to the fiberglass. For a given amount of catalyst and promoter the material cure time increases as the ambient temperature decreases; and for a given temperature the material cure time increases as the proportion of promoter and/or catalyst decreases. In order to cover the required temperature range of +40°F to +95°F both catalyst and promoter proportioning must be variable. This can be accomplished with variable delivery metering pumps. For proper resin to fiberglass proportioning the resin flow and vehicle speed must be controllable. This can be accomplished by controlling resin pump speed and vehicle travel speed. The procedures for accomplishing the required materials dispensing control are explained below for the high rate system. General procedures are:

1) For a given surfacing weight per square foot, determine the number of layers and weight per square foot of surfacing constituents required, and the fiberglass width and placing arrangement.

2) Determine the travel speed and resin flow rate.

3) Determine the surfacer engine speed and transmission setting.

4) Determine catalyst and promoter settings.

Step 1--As an example assume that the required surfacing weight is 2 lb/sq ft and that the lap arrangement is per Figure 14 for the 2 layer surface, and that the fiberglass is .4 lb/sq ft, 6.5 ft wide Fabmat C-4020. This then determines the fiberglass spindle and spraybar arrangement, and allows setting of the driver's alignment guide.

3.3.1.4 Material Dispensing (Cont)

Step 2--Referring to Figure 17, with the width and weight of glass known a resin flow of 76 GPM at 100 ft/min travel speed is indicated. The vehicle engine speed and transmission settings to achieve this speed may be determined from charts available to the driver.

When surfacing over porous soils it may be necessary to increase the amount of resin applied to the fiberglass. Quantitative data is not yet available, however if it is desired to apply resin at rates different from the .6 lb per square foot per layer used as the basis for Figure 17, or when using resins of a different density; different ground speed versus pumping rate curves would have to be consulted. Using the example above, but reducing the travel speed to 80 ft per minute would increase the liquid coverage weight from .60 lb per square foot to .75 lb per square foot. Liquid output may also be independently varied but the amount of variation may be limited by the nozzle capability to maintain a good fan.

Step 3--Referring to Figure 18 for a required flow of 76 GPM, the surfacer engine speed should be either 1,730 or 2,750 rpm depending on the transmission range selected.

Step 4--Requires that a reference temperature on which to base the metering pump settings be known. The length of time required to cure is affected by air, soil and resin temperature, sunlight, and moisture. The surface air temperature is considered most relevant for selecting a starting point. However, the resin temperature as well as weather conditions should be taken into account. On warm sunny days or if the resin is significantly warmer than the surface temperature the material will tend to gel faster and promoter and/or catalyst proportions should be slightly reduced. The opposite is true if the weather is cool and cloudy or the resin is cold. Experience with the system will enable adequate evaluation of these factors. The gel time should occur within about 10 to 30 minutes after application to allow sufficient time for rolling the surface and to cure early enough to permit traffic within 1 hour. The gel time should be checked when the equipment is initially readied for use and should be adjusted if necessary before starting the actual surfacing.

Referring to Figure 19 for an assumed temperature of 60°F the catalyst pump should be set to either 60 or 90 and the promoter pump to either 58 or 36 respectively. If the temperature could be expected to rise during the surfacing activities, selecting the lower catalyst setting would be logical. Conversely if the temperature could be expected to drop, the higher catalyst setting should be selected.

Similar procedures would be required using the low rate unit except that the resin is distributed manually instead of through regulation of the vehicle speed as with the high rate unit.

The above procedures require that the speed of the resin, promoter, and catalyst pumps have a constant ratio at all times. If this were not the case, a separate chart equivalent to Figure 19 would be required for each change in speed ratio between the resin pump and the metering pumps.

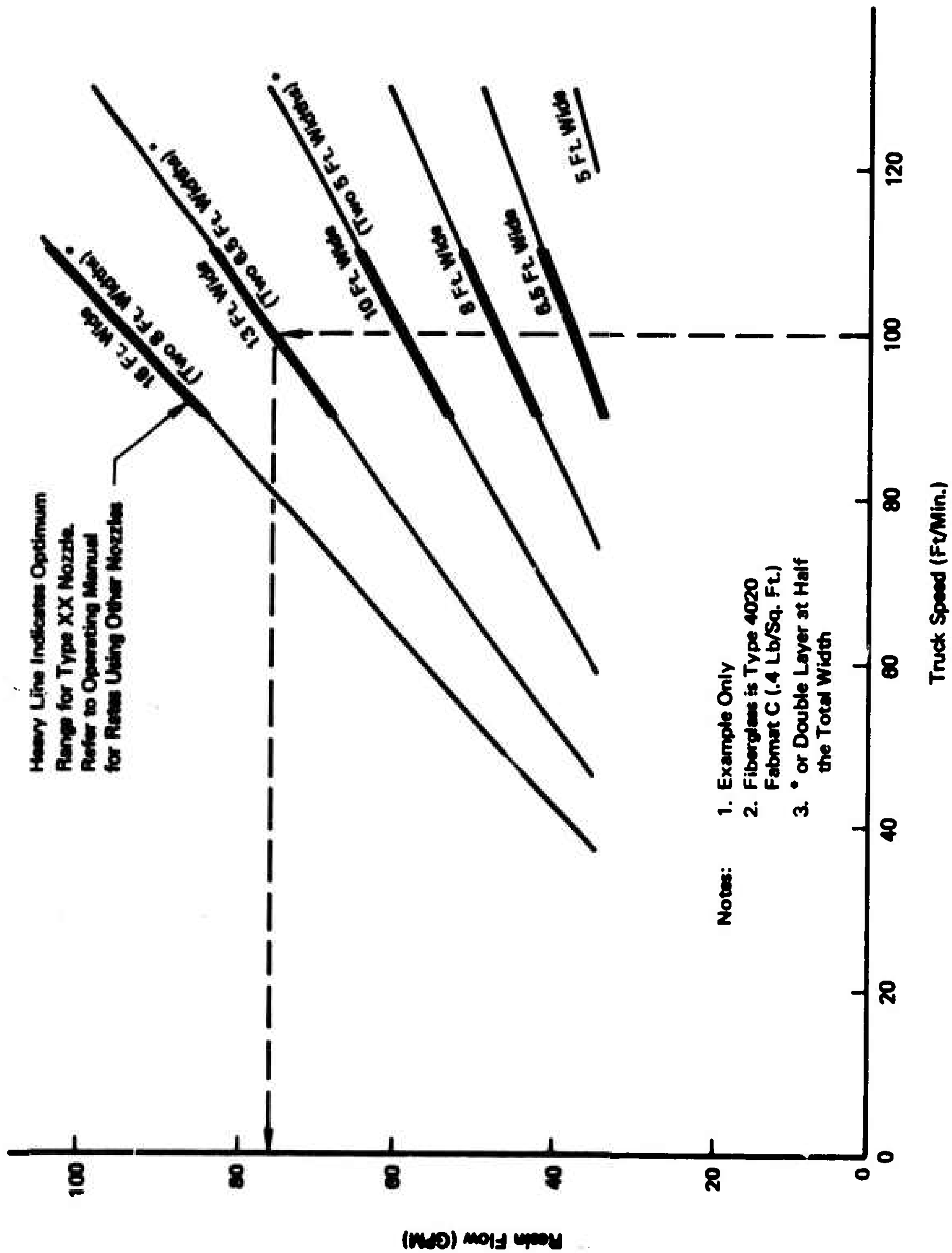


Figure 17 : RESIN APPLICATION RATES FOR VARIOUS FIBERGLASS WIDTHS

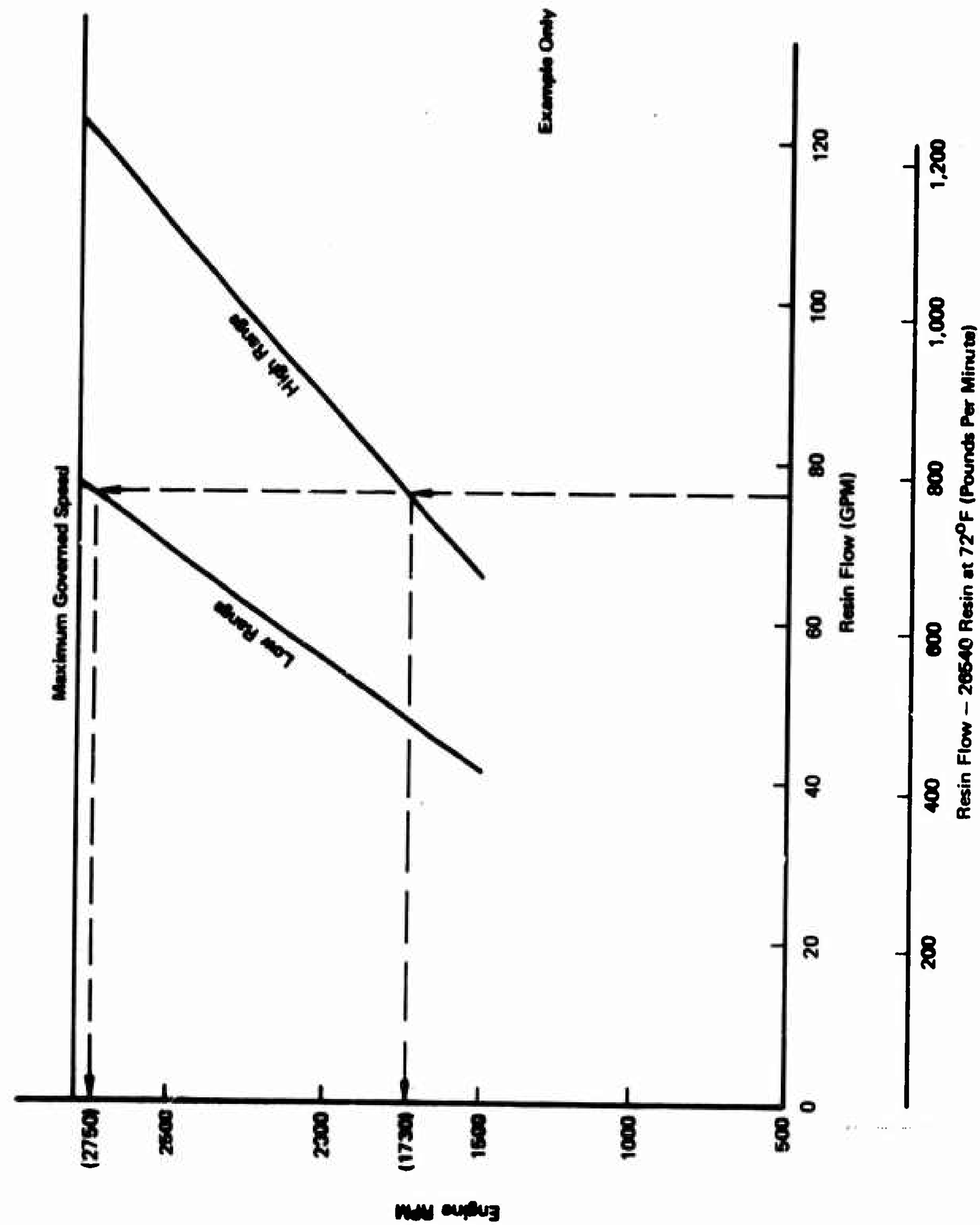


Figure 18: ENGINE SPEED VS RESIN FLOW

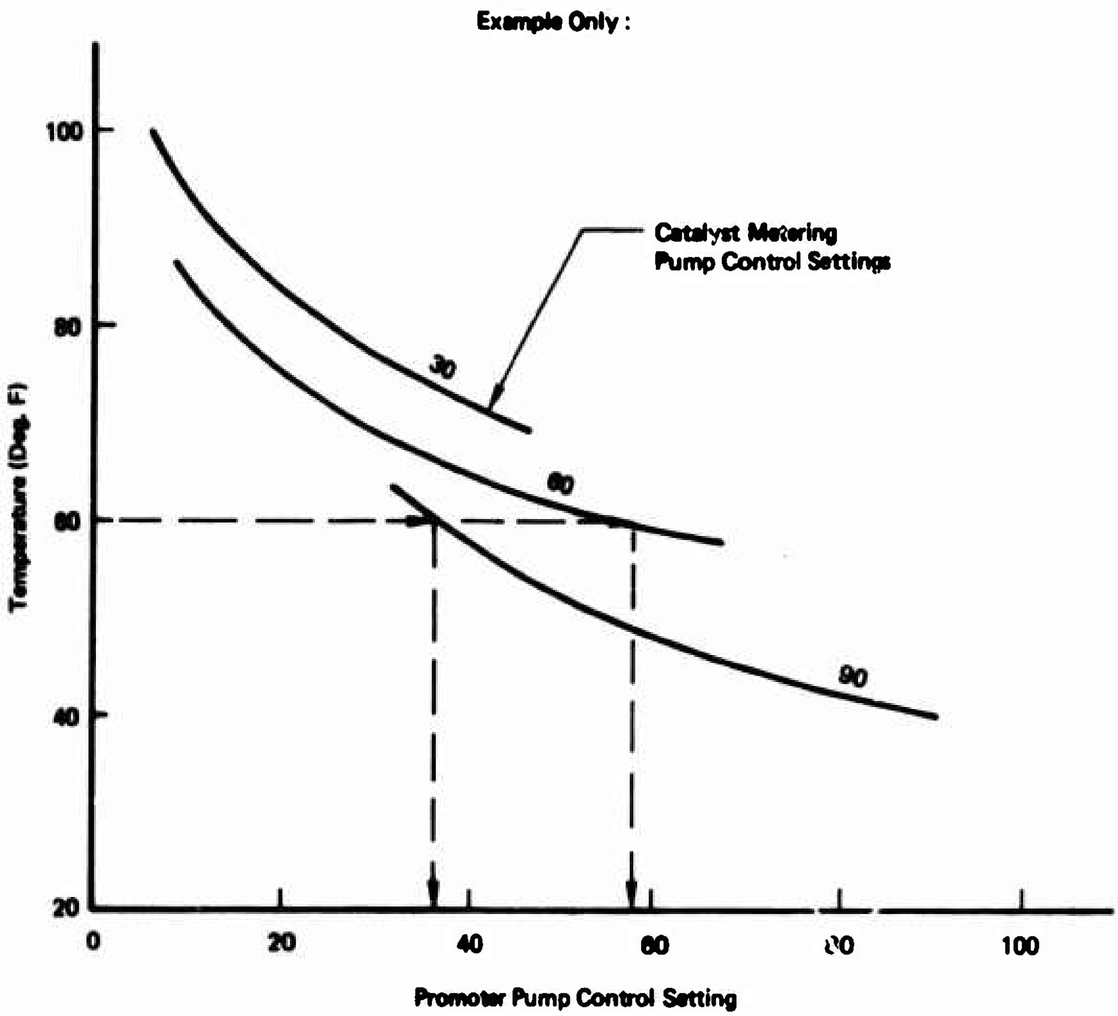


Figure 19: CATALYST – PROMOTER PROPORTIONING

3.3.1.4 Material Dispensing (Cont)

Preliminary requirements for liquid materials dispensing and liquid densities are shown in Table 9. The basis for the values in Table 9 includes 60:40 liquid to fiberglass ratio with minimum and maximum promoter and active catalyst proportions of .25 PHR (parts per 100 parts resin by weight) and 1.5 PHR respectively, and provides the following capabilities:

The maximum resin flow rate of high rate equipment is that required to simultaneously apply two strips of 8 ft wide .4 lb/sq ft fiberglass at a vehicle travel speed of 100 ft/min. The minimum rate will allow application of a single 5 ft wide strip of .4 lb/sq ft fiberglass at 120 ft per minute or two strips of 6.5 ft wide .4 lb/sq ft fiberglass at 37 ft/min. All rates are based on a nominal 60:40 liquid to fiberglass ratio. This may be varied by changing either travel speed or pumping rate.

The maximum resin flow rate of low rate equipment is based on a coverage rate of 163 sq ft/min with .4 lb/sq ft fiberglass at a liquid to glass ratio of 60:40. The minimum flow rate will allow a coverage rate as low as 70 sq ft/min with .4 lb/sq ft fiberglass.

The range of catalyst and promoter variation should provide for a 10 to 30 minute gel time at any resin flow between the limits stated above at temperatures from +40°F to +95°F.

3.3.1.5 Equipment Development

Past research and development conducted relative to rapid site surface preparation has resulted in the development of two sets of surfacing equipment. Each set consisting of a somewhat mechanized high rate surfacer and a low rate manual system. One set of equipment developed under contracts administered by the U.S. Marine Corps resulted in the On-Fast surfacing system. The other set of equipment developed under contracts administered by the U.S. Air Force resulted in the Rapid-Site surfacing system.

3.3.1.5.1 On-Fast Equipment System

The On-Fast equipment system is composed of two prime items. A high rate surfacer and a low rate manual spray unit (MSU). Both items employ three component fluid systems (resin, catalyst, and promoter) with chopped strand fiberglass mat up to 11-1/2 feet wide of various thicknesses employed as reinforcements.

The surfacer is a trailerized unit which is equipped with large, low pressure tires enabling travel over soft sand. It blends and dispenses catalyzed and promoted resin through separate spraybars at a rate of 860 pounds per minute (approximately 90 GPM) total and applies the resin to the 11-1/2 ft wide strip of matting which is unrolled ahead of the spraybars. The application rate is controlled by adjusting the towing speed which is displayed to the tow vehicle driver through a speed sensor on the surfacer. Resin is pumped from two on-board throwaway containers of 315 gallons each. Benzoyl peroxide catalyst and dimethyl aniline promoter are drawn from 30 and 15 gallon standard size steel containers respectively and metered into the resin in amounts required to maintain a satisfactory cure time under varying

Table 9: LIQUID MATERIALS DENSITY AND DISPENSING REQUIREMENTS

Liquid Materials Density

Material	Density — Lb/Gal		
	40^oF	72^oF	95^oF
Resin – PPG (5000) SC 19-143	9.25	9.12	9.04
Resin – Hetron 26540	10.32	10.20	10.10
Promoter – Dimethyl Aniline	8.05	7.95	7.87
Catalyst – Noury S0046	Nominal 9.8 Lb/Gal		

Liquid Materials Dispensing Requirements

High Rate Surfacer		
Material	**Maximum**	**Minimum**
Resin	952 *PPM	342 PPM
Promoter	14.1 PPM	0.8 PPM
Catalyst (Emulsion)	34.6 PPM	2.2 PPM
Low Rate Surfacer		
Resin	97 PPM	40 PPM
Promoter	1.5 PPM	0.1 PPM
Catalyst (Emulsion)	3.6 PPM	0.2 PPM

*Pounds per minute

3.3.1.5.1 On-Fast Equipment System (Cont)

environmental conditions. A 250 foot long strip of surfacing may be completed without recharge of liquids or matting. The surfacer also contains a cleaning system consisting of a 55 gallon drum of methylene chloride solvent and the necessary pump and plumbing to clean all or selected sections of the fluid system.

The surfacer weighs approximately 13,500 pounds loaded and 4,500 pounds empty. During operation it is towed by a bulldozer or tractor at speeds ranging from 40 ft per minute to approximately 80 ft per minute. Surfacing operations also require a rough terrain forklift of at least 3,200 pounds capacity for handling resin, glass, solvent, and catalyst. No specific site preparation equipment is provided as part of the system. However, prior to surfacing areas such as helipads, the site should be graded smooth and cleared of protruding vegetation utilizing conventional construction equipment. No other powered equipment is required. During a typical surfacing task a nine man crew is adequate. However, the addition of a second shift and two more men improves productivity. The system is operable under cool and wet as well as windy conditions since the curing system used is effective in the presence of moisture and the fiberglass matting is sprayed with resin as it is unrolled onto the ground.

The MSU is a palletized pumping unit that utilizes the same liquid materials as the surfacer. Catalyzed and promoted resin is supplied to a two nozzle, hand held spray gun through separate flexible hoses at a rate of 55 lb/min total. The chopped strand fiberglass mat of various widths and weights is laid out manually prior to wetting with resin.

The unit weighs approximately 945 pounds and may be positioned on a truck or trailer, or on the ground. Resin, catalyst, promoter and solvent are normally supplied to the machine from the same type containers used with the surfacer. They may be positioned anywhere within reach of the 10 foot supply hoses, provided the liquid level is initially above the respective pump inlet ports. A forklift is normally required for replacing resin and catalyst containers. However, a separate supply vehicle can be positioned within each of the supply hoses for remote site operations if desirable. Site preparation requirements are generally the same as for the surfacer but depend to some degree on the finished surface appearance required. No other powered equipment is required. A typical surfacing task requires 5 men; one machine operator, one spray gun operator, one hose handler, and two glass handlers.

3.3.1.5.2 Rapid-Site Equipment System

The Rapid-Site equipment system is also composed of two prime items, the high rate Integrated Spraying System (ISS) and a lower rate unit with a hand held spraybar called the Mini-System. Both applicators employ two component fluid systems (pre-promoted resin and catalyst) and a composition woven roving/chopped strand mat that is applied in a separate operation.

3.3.1.5.2 Rapid-Site Equipment System (Cont)

The ISS consists of a gasoline engine powered pumping unit which dispenses pre-promoted resin and catalyst and is supported by four resin tank trailers of approximately 500 gallons each, two tractor mounted glass dispenser/rollers, a trencher, a resin transfer pump, a roller wash tank, a portable solvent pump and various items of miscellaneous support equipment. The pumping unit is mounted on a modified commercial truck chassis and the vehicle speed is controlled to maintain proper application rates. The tank trailers are filled from 55 gallon drums using a resin transfer pump and are then connected to the dispensing unit as needed during spraying operations. The pumping unit applies resin and catalyst to the glass through separate spray nozzles in a side mounted spraybar assembly at a rate of 20 GPM or as an alternate, through a hand held spraybar assembly on a flexible hose at 15 GPM. The catalyst application rate is variable to compensate for a range of ambient temperatures. Two tractor mounted combination glass dispensers and rollers are used to apply and roll the glass at a rate that matches the resin dispenser. Each pass of the roller/dispenser applies a strip of glass and simultaneously rolls a portion of the dry glass and a section of resin wet glass. After each pass the roller must be washed with solvent to prevent an accumulation of cured resin.

The Rapid-Site Mini-System is a palletized, gasoline engine powered, pumping unit that utilizes the same materials as the ISS. The resin and catalyst are dispensed through separate spraybars in a hand held applicator at the end of a flexible hose. The rate of application is controlled by operator walking speed. Resin is drawn from 55 gallon drums.

The fiberglass mat is applied manually from rolls. After it has been wet with resin, the surface is manually rolled to properly saturate the matting and reduce voids. As with the high rate equipment the catalyst flow rate is variable to provide an acceptable cure time with varying ambient temperature.

3.3.1.5.3 Advanced Surfacing Systems Equipment Development

The On-Fast surfacer though capable of high dispensing rates is not self-propelled and is not capable of meeting the required continuous application rate of 10,000 square feet per hour. The manual spray unit is also incapable of meeting the required 2,000 square feet per hour application rate. The unit was designed to dispense 55 pounds of liquid per minute. This would require that the equipment be dispensing liquids approximately 46 minutes per hour, and this would not allow sufficient time for other required tasks such as glass rollout, unproductive travel, and switching resin containers.

In addition, the Advanced Surfacing Systems involve several new design requirements such as night lighting provisions and -25°F to +125°F equipment operation that were not considered in development of the On-Fast equipment.

The Rapid-Site ISS is also incapable of meeting the required high rate application. Both the ISS and the lower rate Mini-System were designed to use a two component material system which does not possess the required curing capability over a wide temperature-moisture range.

3.3.1.5.3 Advanced Surfacing Systems Equipment Development (Cont)

Though none of the previously described systems fulfills all requirements of the Advanced Surfacing Systems, many components such as engines, pumps, valves, hoses, gauges, containers, and similar items have been successfully used with materials similar to the advanced surfacing system materials. Some development testing will be required to ensure thorough internal and external blending of ingredients, to ensure proper material dispensing rates, to define field application techniques and possibly other areas unknown at this time. This is considered normal design integration practice however and no state-of-the-art advances will be required.

Crew training and development of operating procedures that will enable the planned surfacing rates to be achieved will require some effort after the systems are placed in service. This could probably be best accomplished through full scale surface application with careful preplanning, observation and evaluation of the project. Tables 10 and 11 present a summary of previously developed equipment system items, applicability to, and new developments required for the Advanced Surfacing Systems high and low rate equipment respectively.

3.3.1.6 Ecological Considerations

Information concerning possible harmful effects on the ecology of the surfacing materials including fiberglass, resin, catalyst, promoter and solvent or combinations thereof was sought from material suppliers, available literature, the Washington State Department of Ecology, the Environmental Protection Agency and the Food and Drug Administration. A complete and unqualified answer to this question would require extensive testing and is beyond the scope of this study. Therefore, the information presented is that gleaned from analysis of data obtained from the aforementioned sources. Nearly all information in this field is concerned with the health and safety of personnel and though indicative of ecological effects, is not directly applicable. A detailed summary of the ecological impact of the surfacing material system and its respective components may be found in Table 12.

Fiberglass reinforced polyester resin when properly cured does not appear to present any serious ecological hazards. Though the resin deteriorates under ultraviolet radiation, the decomposition is very slow, having been cited as about 1 mil per year under southern California conditions. Dimethyl aniline in the resin, which in the free state is highly toxic to humans, is not believed in itself to be cause for alarm when employed as part of the resin system. Polyester resin containing up to .4% N, N- Dimethyl aniline by weight of cured resin may be safely used as articles intended for repeated use in contact with foods (Reference 12). Based upon decomposition of cured resin containing 1.5% dimethyl aniline, at a rate of .001 inches per year the quantity released per year would amount to approximately .04 pound per 10,000 square feet of surface area. However, the rate of decomposition, the exact substance released, and the effect of these substances may vary with the type of resin and the degree of cure. The ratio of curing agents and the degree of cure achieved with field applied surfacing could vary considerably from the types of materials previously tested for toxicity. Thus there could be an adverse effect on water quality when exposed to the surfacing material. Therefore, the only reliable means of determining whether the material in question is harmful is to test it under actual or simulated conditions of application and use.

Table 10: *HIGH RATE SYSTEM DEVELOPMENT SUMMARY*

System Item	Previously Developed	New Development
High Rate Surfacer	Previously developed Rapid-Site and On-Fast high rate surfacers will not meet the required 10,000 sq ft/hr output. Both systems are also deficient in other detail requirements.	A new item of equipment is required which integrates components which, so far as is known, are either available from commercial suppliers or similar to previously developed items.
Truck	A vehicle modified for low speed capability is commercially obtainable.	Must interface with many other system elements.
Base Structure	None Available.	Basic Structural design.
Boom & Turret – (Fiberglass & spraybar positioning.	Off-the-shelf hydraulically powered boom.	Requires minor modification and integration with structure and hydraulic power.
Power & Power Transmission	All major power and power transmission components are available commercially.	Integration of off-the-shelf components
Fluid Dispensing	All major components are available commercially. Satisfactory metals, seals, hoses, and surface finishes are available. Previously developed throwaway resin containers are usable with minor modification	Integration of components required. Dispensing tests of components and the complete system required to ensure satisfactory flow rates, material blending and system operation
Fiberglass Dispensing	Previously developed guidance and dispensing techniques may be applicable. Simultaneous dispensing of two rolls has not previously been done.	Some unknown amount of effort required to develop proper techniques relative to minimizing wrinkles, achieving thorough glass wet-out and avoiding possible problems not presently known.
Surfacing Rolling	Surface rollers developed during Rapid Site program.	Improved fiberglass cutting methods should be investigated. Rolling techniques and roller cleaning methods must be investigated considering the detail requirements of this program
Construction Procedures	Satisfactory edge anchoring and lapping techniques have been developed with both previous systems. Satisfactory two layer surfaces have been applied during the Rapid Site program.	No satisfactory expansion joints have been developed to date. Prior to constructing large areas this should be investigated. Evaluation of laps and edging should be continued during field operations.
Application	The basic application procedures have been developed during previous programs. Surfacing for helicopter pads, VTOL pads, and many diverse applications has been constructed using both manual and powered equipment.	Development of detail operating procedures will require investigation into materials loading; vehicle guidance; rolling technique and roller cleaning, safe, efficient operating techniques; and crew coordination. Crew training will be required to achieve required application rates.

Table II: LOW RATE SYSTEM DEVELOPMENT SUMMARY

System Item	Previously Developed	New Development
Low Rate Surfacer	Rapid Site Mini-System is not compatible with the three component fluid system required to meet the operating temperature range under high humidity. On-Fast Manual Spray Unit is designed for lower output than required and does not meet other detail requirements imposed under this contract.	A new item of equipment is required. All major components except structures are, as far as is known, either available from commercial suppliers or similar to previously developed items.
Trailer	Trailers of the required capacity which conform to MIL-M 008090E and MIL-A-8421 have been developed. A suitable trailer using developed components assembled to match the specific requirements of this system can be supplied by equipment manufacturers.	Trailer must interface with material dispensing equipment and tow vehicles.
Base Structure	None Available	Basic structural design
Power & Transmission	High rate system comments are applicable.	High rate system comments are applicable.
Fluid Dispensing	High rate system comments are applicable	High rate system comments are applicable.
Fiberglass Dispensing	Previous low rate systems used manual rollout.	Glass handling employing a yoke requires some investigation into techniques to minimize wrinkling and provide easy lap spacing. Glass cutting methods should be investigated.
Surfacing Rolling	Hand rollers have been used in both previous programs and in industry.	Development of best roller design and rolling techniques require field investigation.
Construction Procedures	Satisfactory edge anchoring and lapping techniques have have been developed with both previous systems. Satisfactory two-layer surfaces have been applied during the Rapid Site program.	No satisfactory expansion joints have been developed to date. Prior to constructing large areas this should be investigated. Evaluation of laps and edging should be continued during field operations.
Application	The basic application procedures have been developed during previous programs. Surfacing for helicopter pads, VTOL pads, and many diverse applications has been constructed using both manual and powered equipment.	Development of detail operating procedures will require investigation into materials loading; vehicle guidance; rolling technique and roller cleaning, safe, efficient operating techniques; and crew coordination. Crew training will be required to achieve required application rates.

Table 12: ECOLOGICAL IMPACT (Sheet 1 of 3)

Material	Impact Potential	Countermeasures	Waste Disposal
<u>Surfacing System</u> Combined Polyester Resin, Promoter, Catalyst, & Fiberglas	1. Relatively inert. Slow decomposition in sunlight. Not believed harmful to ecology or personnel health, but field applied material could release substances that would have an effect on ecology or health. 2. Flammability varies with resin type and glass content but is not high. Toxicity of resulting fumes has not been investigated. However, per one resin manufacturer it is not appreciably worse than a wood fire, the products of combustion being CO, HCL and carbon. 3. Temporary degradation of air quality during surfacing operations. 4. Applications which prevent erosion or water contamination through containment of harmful wastes would be beneficial.	1. Additional research as well as testing would be useful. 2. Do not expose to fire or heat; provide respiratory protection for firefighters. 3. Avoid working immediately downwind of uncured surfacing Do not apply large areas in inhabited areas when weather conditions will allow an accumulation of vapors.	Surfacing may be cut up and treated as solid waste. Material may be burned though the techniques required to do this have not been investigated in this study.
<u>Styrene Monomer</u> Vapor Density 3.6 (Air = 1.0) Vapor Press. 4.9 MM @ 85°F Styrene is considered the most harmful component of resin. Basic resin is relatively inert.	1. Moderate fire and explosion hazard. 2. Toxic vapors. (*TLV – 100 PPM) 3. Probably harmful to aquatic life.	1. Keep away from heat & flame. 2. Avoid spills, provide ventilation, work upwind of uncured surfacing. 3. Avoid spills or discharging waste into waterways.	Add promoter and catalyst to resin before disposing of more than a few gallons. Promoter and catalyst emulsion each should not exceed 1% and 2.5%, respectively by weight of resin to avoid excessive vapors from heat.

*TLV = Threshold limit values.
Definition per Reference 13.
"Conditions under which it is believed that nearly all workers may be repeatedly exposed day after day without adverse effect."
Values were obtained from Reference 15.

Table 12: *ECOLOGICAL IMPACT (Sheet 2 of 3)*

Material	Impact Potential	Countermeasure	Waste Disposal
<u>Catalyst</u> 40% Benzoyl Peroxide in Dibutyl Phthalate carrier. Density : 1.175 Benzoyl Peroxide is a solid at room temperature. Melting point is 217-222°F. It decomposes ex-posively slightly above this temperature.	1. Oxidizing material, insoluble in water, products of breakdown not believed harmful to soil or water supply. 2. Irritating to skin, mucous membranes and eyes. No high toxicity reported. 3. Fire and explosion hazard if the carrier liquid is allowed to evaporate or leach out or if heated.	1. Avoid spills. 2. Avoid prolonged or extensive contact, keep away from eyes, avoid breathing concentrated vapors. 3. Promptly clean up spills; do not store in open containers. Do not allow the catalyst to exceed 100°F.	Combine with promoted resin. Promoter and catalyst emulsion each should not exceed 1% and 2.5% respectively by weight of resin to avoid excessive vapors from heat.
<u>Promoter – Dimethyl Aniline</u> Density: 0.9557 @ 20°C, H_2O @ 4°C = 1.0 Vapor Density: 4.17 Melting Point: 36.5°F Vapor Press: 1 MM @ 85°F	1. Highly toxic in vapor or liquid form when ingested through lungs, stomach or unbroken skin. * TLV = 5 PPM 2. Emits highly toxic fumes when heated. Vapors are more dense than air. 3. Flammable when heated. 4. Could adversely affect water quality but is not soluble in water. 5. Adverse effect on air quality though volatility is low. 6. Toxic materials could possibly enter plants growing in contaminated soil through break-down of DMA into soluble substances.	1. Avoid contact with personnel; keep DMA in closed containers; the best way to prevent pro-blems is to avoid waste; no spills, leaks or residual discarded material. 2. Firemen should wear respiratory protection. 3. Keep away from heat or flame. 4. Clean up spills to prevent con-tamination of ground water; do not dump waste into sewers or waterways. 5. Adequate ventilation required particularly in closed areas. 6. Clean up spills.	Combine with promoted resin. Promoter and catalyst emulsion each should not exceed 1% and 2.5% respectively by weight of resin to avoid excessive vapors from heat. Ensure that containers are emptied and rendered unserviceable before they are discarded. If they are accessible to personnel they should be washed and destroyed before discarding.
<u>Fiberglass</u>	1. Irritating to skin of persons handling the material. 2. Not believed harmful to other life forms or to air or water.	1. Practice good personal hygiene & minimize direct skin contact.	Treat as solid waste

Table 12: ECOLOGICAL IMPACT (Sheet 3 of 3)

Material	Impact Potential	Countermeasures	Waste Disposal
Solvent – Methylene Chloride Density: 1.33 Vapor Density: 2.93 Vapor Press: 380MM @ 72°F Ign. Temp. 1224°F	1. Vapors are moderately toxic * TLV = 500 PPM 2. Highly volatile – Spills evaporate rapidly with cooling effect – No probable lasting effect. 3. Liquid is irritating to skin and mucous membranes and can damage eyes. 4. Emits toxic vapors when heated or burned. 5. Not a fire hazard.	1. Avoid breathing concentrated vapors. 2. Avoid skin contact in cool weather. 3. Avoid prolonged or extensive skin contact, keep away from eyes and mucous membranes. 4. Keep away from heat or flame.	Allow it to evaporate. Do not add methylene chloride to waste containers where resin, promoter, and catalyst are being combined.

3.3.1.6 Ecological Considerations (Cont)

Considering the evidence received thus far and the fact that fiberglass reinforced resin is in widespread use in such applications as roofing, swimming pools, boats, and containers used in performing bio assay tests by the Washington State Ecology Department, it is considered highly probable that the surfacing is harmless. This should be verified however before the material is used in applications where personnel are exposed to large areas for long duration or where buildup of toxic materials is possible such as in potable water reservoirs or fabrication of buildings intended for human habitation.

The effect on plant and animal life because of the presence of surfacing is considered to be neither more nor less harmful than other common surfacing methods such as concrete. Most plant and animal life would probably not survive beneath the surface. However, the material may be cut up and removed with no probable lasting effects on the ecology. Many possible applications would be beneficial to the environment through soil erosion control, or containment of harmful wastes.

During application and curing of the surfacing the local air quality is adversely affected by the giving up of malodorous and toxic vapors. The severity is generally greater as the cure is accelerated and less severe but of longer duration as the cure time is lengthened. The composition and toxicity of the vapors is not known but the vapors are believed to be chiefly styrene. Care should be exercised when applying the surfacing to avoid breathing heavy concentrations of the vapors and to avoid conditions where the vapors would drift into populated areas. Styrene vapors are heavier than air, therefore concentrations could build up in low areas. During checkout, surfacing and cleanup operations, uncombined resin, promoter and catalyst should be contained and either combined in cured resin or disposed of by acceptable methods recommended by chemical disposal specialists.

Spillage or leakage of polyester resin is not considered a severe ecological hazard under normal circumstances, since the material is not highly volatile and will eventually cure. The styrene which comprises 30 to 50% of the resin is moderately toxic when ingested, inhaled, or as a skin irritant, and is harmful to the eyes. Spills constitute a moderate fire and explosion hazard and the heated material emits acrid fumes. Outdoor spills may be cured in a short time by adding appropriate amounts of promoter (not to exceed 1% by weight of resin) and catalyst (not to exceed 2.5% catalyst emulsion by weight of resin) after which the cured material may be disposed of as solid waste. Spills or leaks in a confined area can cause an unacceptably high concentration of styrene vapors with attendant explosion and toxicity hazards. Therefore, adequate ventilation is required before working in the area. Spilled resin may be absorbed in various suitable substances, such as floor sweeping compound, for convenient removal. Spills which could find their way into a waterway should be immediately cleaned up. The effect on aquatic life is not known; however, the material should be considered harmful.

3.3.1.6 Ecological Considerations (Cont)

The principal ingredients in the catalyst are benzoyl peroxide, a solid at room temperature and a carrier liquid of low toxicity. Benzoyl peroxide is an oxidizing material and is not soluble in water. In the pure state it is explosive and sensitive to shock, heat and friction; however, as formulated for use it is relatively safe. Catalyst spills if not promptly cleaned up constitute a fire and explosion hazard which worsens as the material dries out. Catalyst may be disposed of by combining the catalyst with a quantity of promoted resin, then disposing of the resultant material as solid waste. An alternate method of disposal is to burn the catalyst. If waste catalyst material is disposed of by burning, a dense black smoke is produced to the detriment of air quality. All physiological effects of the catalyst are not known. Benzoyl peroxide is treated in References 13 and 14 with no mention of high toxicity. However, the material may be harmful to the eyes, mucous membranes and skin. Insidious hazards to water, air, or life systems from residual material or small spills is considered only remotely possible.

Dimethyl Aniline (DMA) is toxic to animal life. It is readily absorbed through the skin, hazardous to the eyes, may be fatal if swallowed, and breathing the vapors is hazardous. Spills or leaks of the material may therefore adversely affect air quality and the health of personnel exposed to the material. It is reported to be insoluble in water; however, it could break down into a soluble though still toxic substance and degrade water quality. Edible plants growing in contaminated soil might also pass the material on with unknown effects.

Procedures employed in using the material should therefore place heavy emphasis on the following:

1) Not allowing free DMA to be spilled or discarded.

2) Prompt removal of DMA from the skin or clothing of personnel. Spills on the skin should be washed off promptly with soap and water. Contaminated clothing, shoes, etc., should be laundered before reuse. Spills in the eye should be treated by immediate copious flushing of the eye with water for at least 15 minutes, after which a physician should be consulted. Protective rubber or vinyl clothing and boots are recommended as are splash proof goggles for personnel liable to direct contact with DMA.

3) Cleanup or deactivation of spilled DMA. DMA may be combined with catalyzed resin and the resultant material treated as solid waste. Alternate method of cleanup is to cover the spill with an inert oil absorbing material; sweep up and place in a plainly marked waste disposal container and buried. The cleaned area should be flushed with plenty of water.

The vapor pressure of DMA is quite low, 1 MM of mercury at 85°F as opposed to 31 MM for water at the same temperature. Though outdoor spills would, as a consequence, probably not result in highly toxic concentrations, plenty of ventilation should be provided when spills or leakage occur inside a building or other enclosure. An extreme hazard would result also from a fire involving DMA where large quanti- of toxic fumes might be generated. The maximum allowable concentration for day

3.3.1.6 Ecological Considerations (Cont)

after day exposure given in Reference 15 is 5 PPM by volume in air with maximum excursions to 10 PPM. The greatest hazard to personnel is probably from untrained personnel disregarding spills or splashes of the material on shoes or clothing. Per Reference 16, persons addicted to alcohol should not be assigned to jobs involving possible exposure to aniline. The physiological action of DMA is, according to Reference 13, similar to aniline although it is believed to be more toxic. The recommended maximum daily exposure given in Reference 13 for aniline is the same as for DMA. A maximum allowalbe aniline concentration in potable water supplies of 5 PPM has been given as found in Reference 15. To minimize the hazards to the health of personnel and to other animal life the standard operating procedures should include the following:

1) DMA containers should be emptied and appropriate precautions taken such as smashing or otherwise destroying the containers to prevent any reuse.

2) Unusable DMA should be properly disposed of. One possible method is to combine the DMA with catalyzed resin which may then be buried. Promoter and catalyst emulsion each should not exceed 1% and 2.5% respectively by weight of resin to avoid excessive vapors from heat.

3) All personnel should be instructed in the hazards of DMA, precautions to be observed, symptoms of overexposure, and action required in the event of accidental contact.

Fiberglass does not appear to present an ecological hazard. Though it causes itching and irritation of the skin of personnel handling the material, with continued use, most workers become hardened to it and the temporary itching, redness or swelling subsides. Experience with the On-Fast system has not revealed any tendency for animals to ingest or use the material for nesting. Since all fiberglass except occasional small patches will normally be coated with resin this should not be a severe problem even if small animals were attracted to the material.

Methylene chloride solvent is used to flush the resin, catalyst and promoter systems. It is highly volatile and the vapors are not highly toxic therefore spilled solvent should not have any profound or lingering effect on the ecology. It is a moderate hazard to personnel health. Breathing the vapors induces anesthesia and vapors may also cause irritation of the eyes and respiratory tract. The liquid is irritating to the eyes and may cause skin burns if held in contact with the skin by clothing or other means. Frostbite is also a possibility in cool windy weather because of the high rate of evaporation. Waste material may be disposed of by pouring it on dry earth away from occupied areas and allowing it to evaporate. Solvent should not be disposed of in ponds or puddles of water since it is heavier than water and will sink to the bottom. The resultant layer of water on top of the solvent will prevent it from evaporating.

3.2.2 SYSTEM ANALYSIS

In order to analyze the operation of the high rate and low rate surfacing equipment, respective areas 100 feet by 500 feet and 100 feet by 120 feet consisting of 2 lb/sq ft surfacing were selected. These sizes coincide with the respective 5- and 6-hour continuous surfacing rates and are compatible with the anticipated glass roll lengths. Good weather and smooth, firm terrain with suitable areas for materials handling and disposal of debris were assumed. Using these areas as baselines, variations which affect the design, operation, or ancillary equipment requirements were considered including such factors as different sized areas, soft or uneven terrain, different material module sizes and inclement weather.

3.3.2.1 Site Planning

For efficient use of the surfacing system, some operational planning is required before starting the surfacing. Assuming that a usage and a site have been established, the following tasks are generally required, with the degree of detail varying for different field situations.

1) Determine soil characteristics

2) Establish surfacing weights and areas

3) Perform site preparation as required

4) Compute material quantities

5) List materials, equipment, and personnel required

6) Determine operating procedures including:

   a) Surfacing sequence

   b) Materials handling arrangement

   c) Construction techniques

Sections IV, V, and VI in Reference 10 provide the best known means of relating soil conditions to site size and surfacing weight required for various wheel loads and downwash environments. For those light load applications where load carrying is not the prime requirement, surface thicknesses less than 1 lb/sq ft should be considered.

The amount of site preparation required is variable depending on specific field conditions and the desired end product. The area prior to surfacing should be free of vegetation or rocks protruding more than about 3/4 inch. Abrupt projections or depressions should be cut or filled to prevent resin runoff or puddling. Since an uneven surface may cause local areas of light and heavy resin content as well as wrinkles, uneven lap widths, and a generally rough appearance, the soil should, where possible, be of uniform density and the surface levelled by a grader.

3.3.2.1 Site Planning (Cont)

For most efficient operation, the site, including all equipment traffic areas, should be reasonably level and capable of withstanding the loading imposed by the surfacing equipment and associated ancillary equipment without requiring planking or matting.

With the surface area, weight and configuration established, the materials may be estimated based on a nominal 60:40 resin to glass ratio and a promoter/catalyst versus temperature schedule in accordance with the equipment operating instructions. However, porous or loose soil may require higher resin ratios.

Material estimates should make allowances for overspray, cleanup, residual, and checkout losses of liquids and for inaccuracy and trimming losses on the fiberglass. A nominal 15 percent excess on liquids and 5 percent on fiberglass is recommended as a conservative figure. For larger areas these figures probably can be reduced, however, on smaller areas losses may be greater. Experience will result in achieving closer estimates. A typical example is contained in the following sections.

In planning the operating procedures, material pre-positioning locations and equipment traffic patterns should minimize unnecessary travel and avoid conflict between vehicles. The surfacing sequence should be planned to take advantage of material modules and equipment capabilities, taking into account such factors as fiberglass roll size, resin container size, and hose length when using the low rate system. Unproductive travel, unnecessary fiberglass trimming, and frequent stops should be avoided if possible. Procedures should emphasize cleanliness with no uncontained spillage of liquids, except for catalyzed and promoted resin. Catalyst spills if allowed to remain constitute a fire hazard and promoter spills present a lingering toxicity hazard.

3.3.2.2 High Rate System

In order to analyze the high rate surfacing system a hypothetical airfield parking area 100 by 500 feet capable of withstanding a 6,750 pound single wheel load with 82 square inches of contact area on a CBR greater than 4 was selected. This is typical of current advanced tactical support aircraft.

3.3.2.2.1 General

Based on the above criteria, and referring to Section VI of Reference 10, for a safety factor of 2.0 a surface thickness of two 1 psf layers is required. Edge traffic is anticipated, therefore a nominal 3 foot buried edge in accordance with Method 1, Figure 15, is assumed on all sides. The site is assumed to be graded and compacted to sufficient strength as required for the surfacing and ancillary equipment. Fiberglass rolls are 6.5 feet wide by 250 feet long and weigh 650 pounds each. Fiberglass is currently available in any width to 13 feet with a maximum length of approximately 250 feet. The 6.5 foot width was chosen as the baseline because it appears to be a good compromise in consideration of the following:

3.3.2.2.1 General (Cont)

1) Ease of handling and transporting

2) Percentage of lap area required

3) Manufacturing capability

4) Bı ı the surfacing equipment design

Resin ·· ıiners each have a capacity of 3,000 pounds. This container size is within current capability and is large enough such that one container will exceed the requirements of one load (2 rolls) of fiberglass on the high rate sufacer. Therefore with two containers aboard, normally one full and one partially full, any surfacing pass may proceed to completion or to the end of the glass rolls by switching to the full container at any point in the pass where the container in use is emptied. Standard size promoter and catalyst containers of 55 gallons for catalyst and 30 gallons for promoter were selected. The basis for selecting these sizes is discussed in Section 3.3.2.2.2. For study purposes the weight of liquids applied to the fiberglass are assumed to consist of 1 PHR promoter, 2.5 PHR catalyst emulsion (1% active benzoyl peroxide) and 100 parts resin. Procedures employed in computing materials required is given in Table 13 and are based on a nominal liquid to fiberglass ratio of 60:40.

The preliminary high rate dispensing equipment configuration assumed for this study is shown in Figure 20. The arrangement includes twin containers of resin, promoter and catalyst. Sufficient space is available for the two planned crew members on the deck, an equipment operator and materials tender. The boom may be rotated to dispense surfacing materials to either side or behind the unit.

The vehicle chosen to dispense the surfacing materials must, in addition to providing the required space, support an approximate payload of 22,000 pounds and be stable under the worst operational conditions of eccentric loading. The vehicle must also have variable low speed capability from 30 feet per minute to at least 120 feet per minute and be capable of a road speed of 55 MPH. Because of the weight distribution on the bed, the side tipping stability needed, and the desirability of good traction and flotation, dual rear axles are desirable. A long wheel base is desirable to permit the addtion of gearing for the low speed requirements. A gasoline engine driven truck conforming to MIL-T-45341 with a gross weight of 43,000 pounds appears to satisfy all requirements when modified for the low speed capability. Although either a gasoline or a diesel engine could satisfy the power and speed requirements, the gasoline engine was chosen because it is less expensive and better suited to the short haul, low mileage operation inherent in this application. Other requirements and capabilities of the truck are contained in Section 3.4.2.

3.3.2.2.2 Operational Analysis

The operational analysis assumes that all ancillary equipment has been driven to the site and is available when needed. All necessary site preparation has been accomplished including installation of an edge anchoring ditch and a guideline at the starting edge, and activation of a disposal area. Materials are trucked to the site in the following packages:

Table 13: MATERIALS REQUIRED FOR 100 FT X 500 FT SURFACE

Required Usable Area:	50,000 Sq Ft
Surfacing Weight:	2 Lb/Sq Ft
Reinforcement:	6.5 Ft Wide x 250 Ft Long x 0.4 Lb/Sq Ft
Total Width with Edging:	106 Ft.
Total Length with Edging:	506 Ft (2 glass roll Lengths Plus Edge Strips at Each End)

- With 6 Inch Laps, Effective Width Per Pass = 6.0 Ft; then

$$\frac{106 \text{ Ft/Width}}{6 \text{ Ft/Pass}} = 17.7 \text{ or } 18 \text{ Full Length Strips.}$$

(1 Strip = 2 Pass Lengths)

- At 4 Rolls Each = 72 Rolls of Fiberglass

Edging for ends requires an additional 200 ft, or 2 more rolls for a total of 74.

- Total Weight at 650 Lbs Per Roll = 48,000 Lbs.
- Liquid at $\frac{60}{40}$ x 48,000 = 72,000 Lbs total liquids*
- Resin at 100 PHR = 69,552 Lbs = 23,2 or 24 Containers at 3000 Lbs Each.
- Promoter at 1 PHR = 696 Lbs, 87 Gal or 2.9 Drums at 30 Gal Each.
- Catalyst at 2.5 PHR = 1,739 Lbs, 177 Gal or 3.2 Drums at 55 Gal Each.
- Solvent: Assume two cleanups at one drum each, plus 1 drum for miscellaneous cleaning and 1 drum for roller washing for a total of four drums.
- To allow for less than 100% utilization the totals transported to the site should be increased to:

		Approximate Net Weight
Fiberglass	78 Rolls	50,700 Lbs
Resin	28 Containers	84,000 Lbs
Promoter	4 Drums @ 30 Gal Ea.	960 Lbs
Catalyst	4 Drums @ 55 Gal Ea.	2,160 Lbs
Solvent	4 Drums @ 600 Lbs Ea.	2,400 Lbs

- Total material weight is approximately 154,000 pounds including 10 percent for packaging.

*Liquid composition is 100 parts resin + 1.0 part promoter + 2.5 parts catalyst

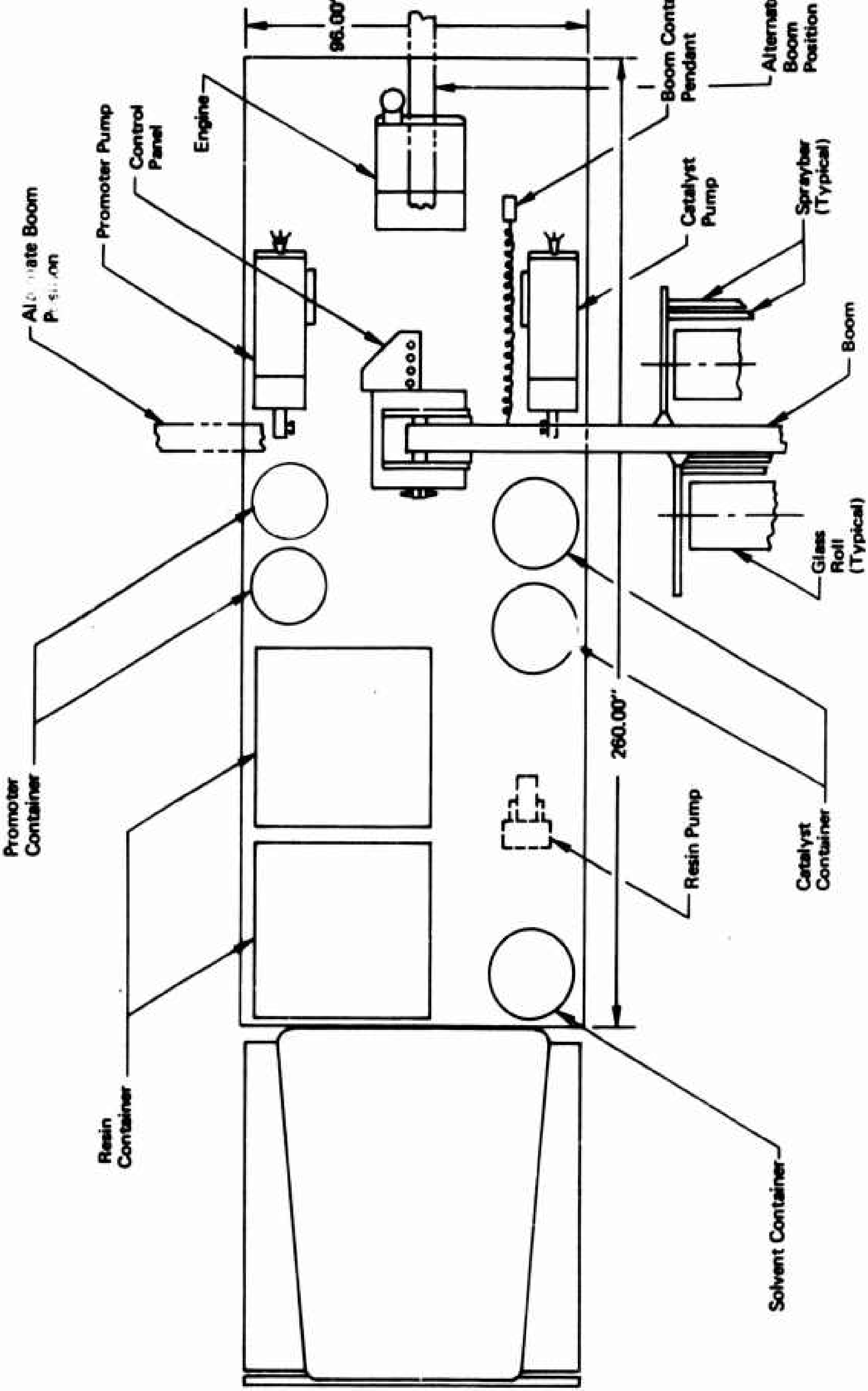


Figure 20: HIGH RATE DISPENSING EQUIPMENT ARRANGEMENT

3.3.2.2.2 Operational Analysis (Cont)

- o Fiberglass-- Throwaway spool, plastic bag moisture barrier, cardboard container, 4 containers per pallet, 650 pounds of fiberglass per container.
- o Resin--3,000 pounds net, fork liftable plywood containers
- o Promoter--30 gallon containers, 4 per pallet
- o Catalyst--55 gallon containers, 4 per pallet
- o Solvent--55 gallon drums, 4 per pallet

Based on the above, a family of task time sequencing charts were developed starting with the prepositioning of surfacing materials at the site. Selected traffic patterns, surface sequencing and material and equipment locations are shown in Figure 3.

Gross tasks are contained in an overall time line, Figure 21. Each of these gross tasks is further broken down in Figures 22 through 28. Detail personnel (identified in Table 14) utilization is shown in Figures 29 through 36 for the most critical portion of the operation, surface application. Material consumption schedule is detailed in Figure 37. Equipment requirements are listed in Table 15.

Examination of the overall time phasing (Figure 21) shows for the example chosen that the estimated total time at the site from materials and personnel arrival until the personnel and equipment are ready to leave is 13-1/4 working hours with an additional 45 minutes required at the equipment storage location for storage preparation. Preparation of equipment can be accomplished at the same time the materials are being positioned up to the point where the system plumbing is filled with liquids. Once the system is filled, long delays should be avoided and surfacing should proceed to completion. Surfacing is then applied on a continuous basis for 306 minutes (slightly more than 50,000 square feet is applied). Since all assigned personnel are busy during the surfacing period, joints and edging cannot start until the surfacing is completed. Edging, expansion joints, and cleanup are then phased in as close as possible on the assumption that the surfacing will support foot traffic 30 minutes after installation and wheeled traffic 60 minutes after installation. The final preparation of the equipment for storage is assumed to take place after transportation to a storage location where vehicles are commonly maintained and held in ready storage.

Materials prepositioning (Figure 22) assumes that materials are delivered either all at once or as necessary to allow uninterrupted placement at the designated spots. Using 12-ton semitrailers such as the M127, seven loads would be required.

During materials unloading, the surfacing equipment crew is readying the equipment. Daily servicing, setting up the spray bars, placement of equipment such as solvent buckets, resin container piercers, tools, and handrollers is accomplished.

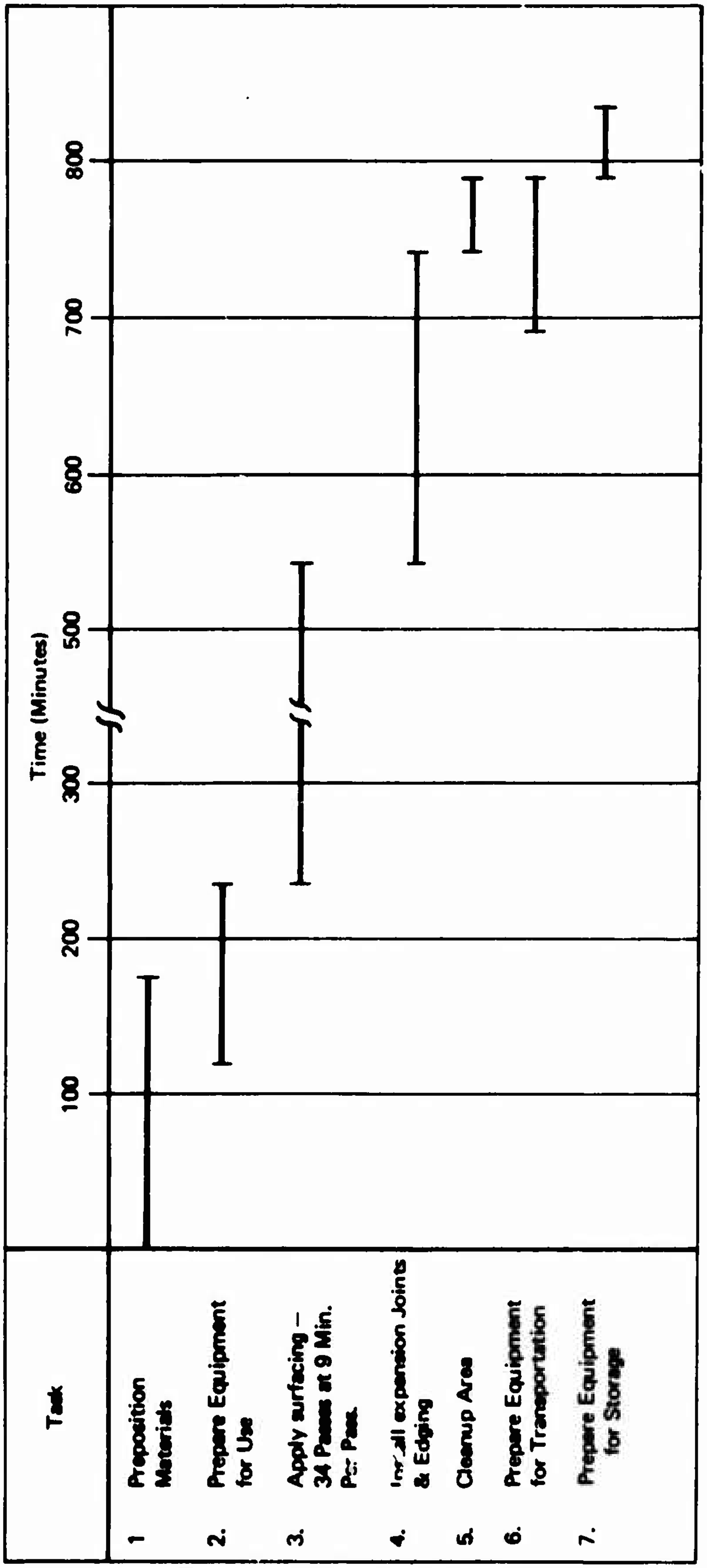


Figure 21 : CONSTRUCT 100 FT x 500 FT SURFACE, HIGH RATE SYSTEM

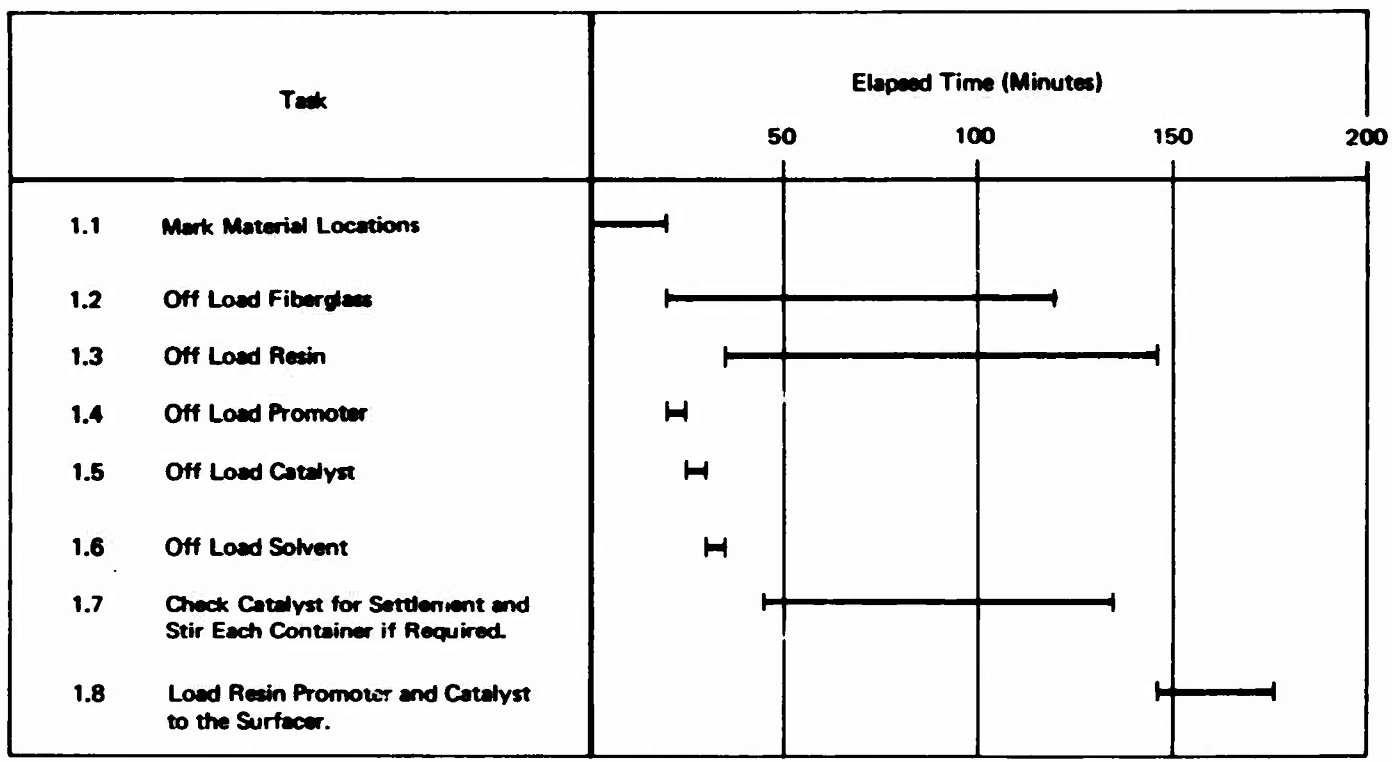


Figure 22 : PREPOSITION MATERIALS – HIGH RATE SYSTEM

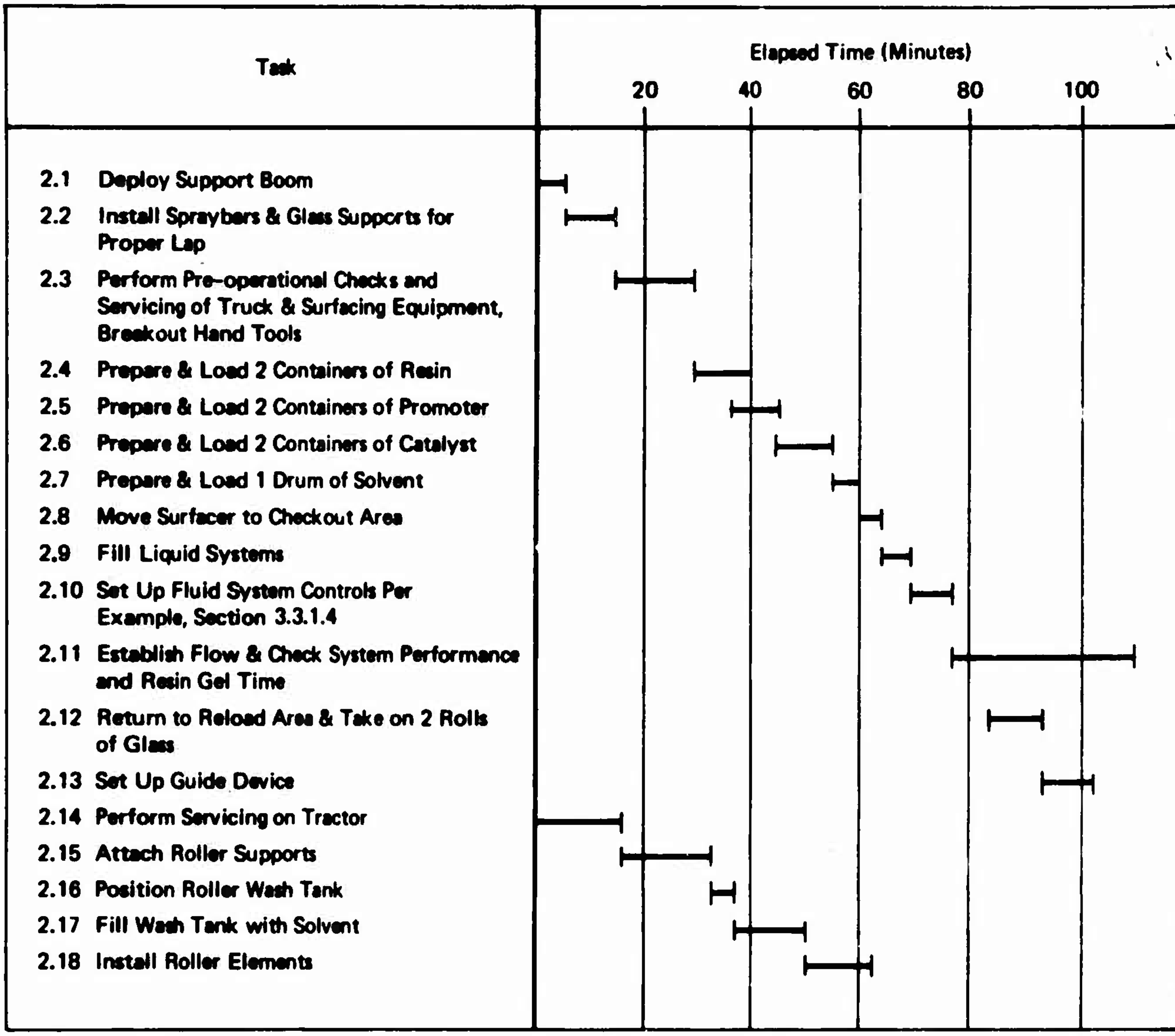
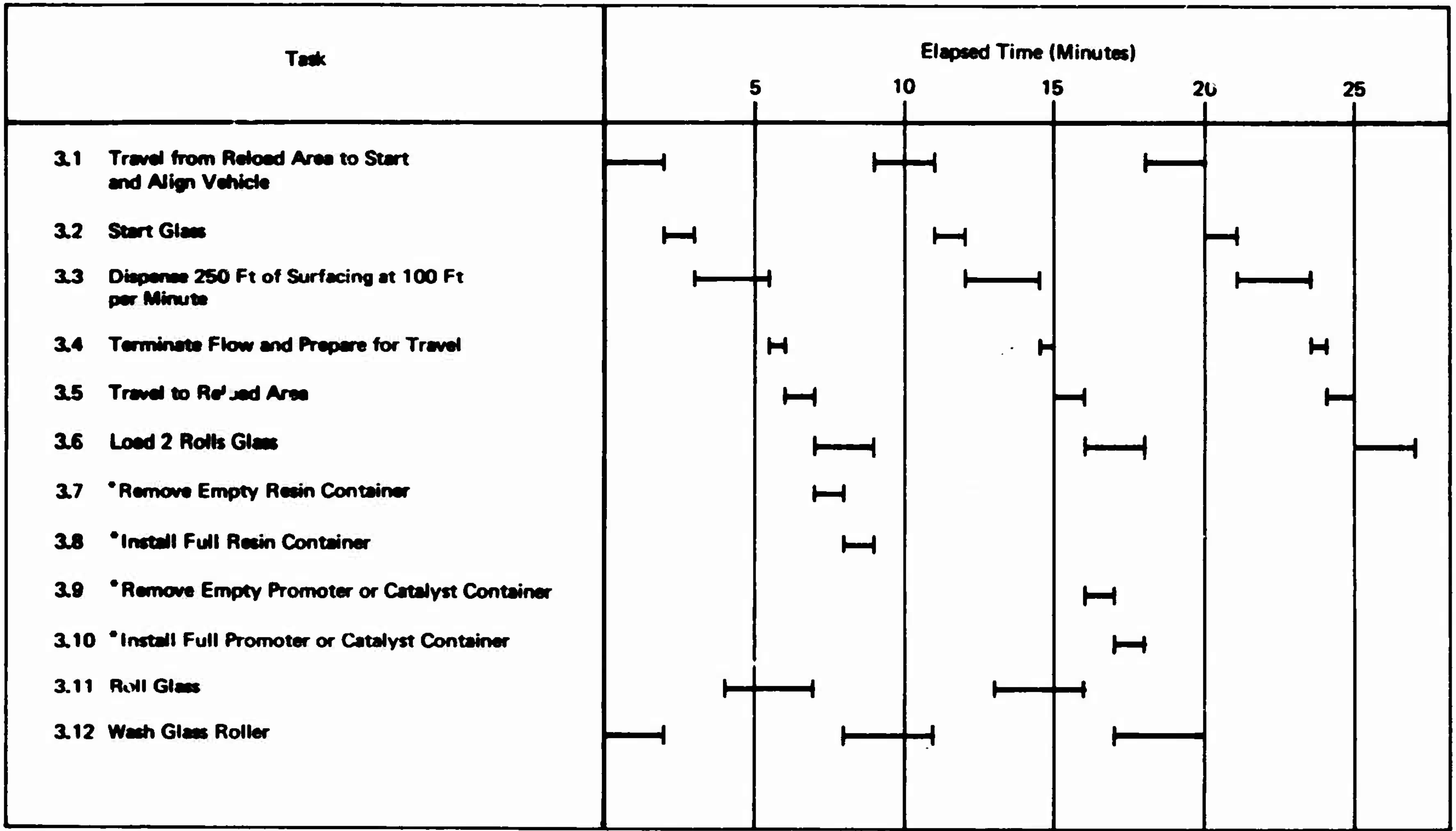


Figure 23: PREPARE EQUIPMENT FOR USE – HIGH RATE SYSTEM



* Replacement of Catalyst or Promoter Occurs During Reload Periods That do not Require Replacement of Resin Containers.

Figure 24: APPLY SURFACING-HIGH RATE SYSTEM (TYPICAL REPEATABLE CYCLES)

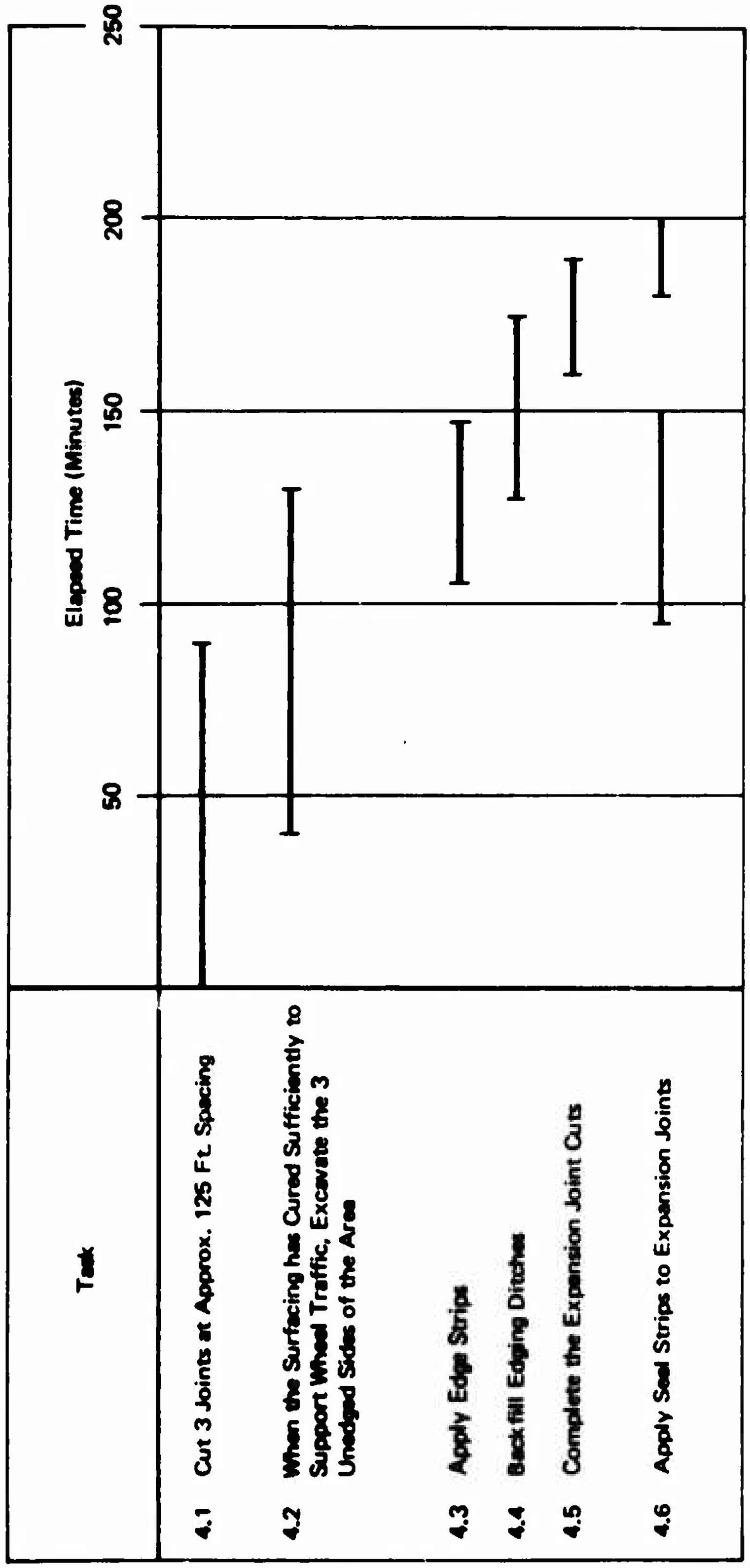
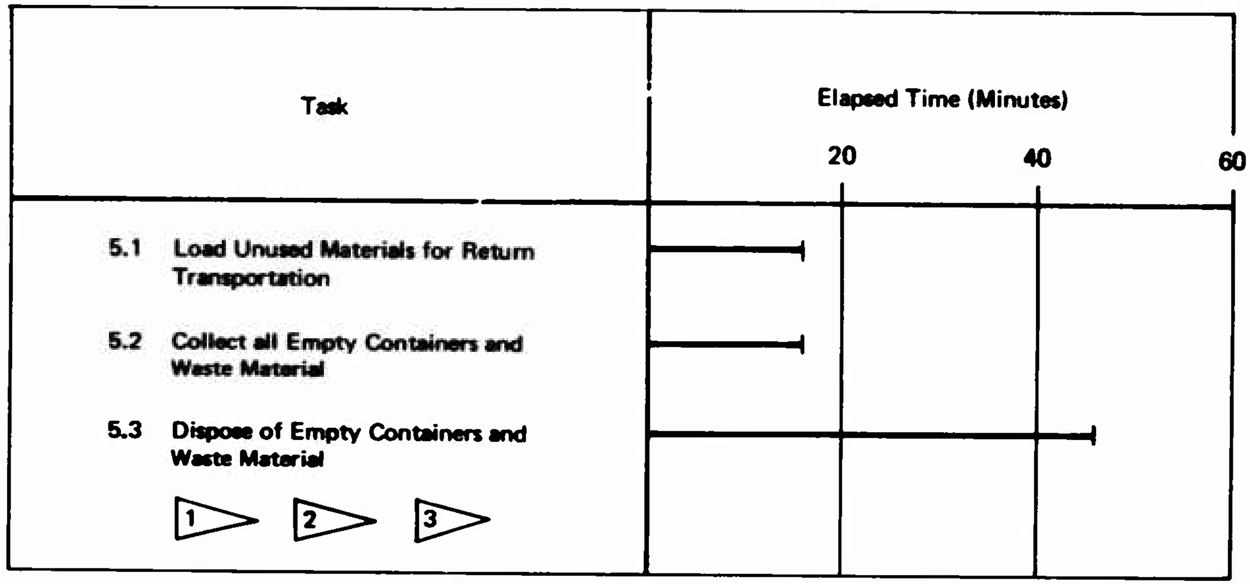


Figure 25 : INSTALL EXPANSION JOINTS AND EDGING– HIGH RATE SYSTEM



1. Waste Promoter, Catalyst, or Resin Should be Mixed with Materials Required to Form Cured Resin Before Disposal.

2. See Section 3.3.1.6 for Ecological Considerations

3. Further Experience with the System in the Field May Reveal Other Suitable Methods of Container Disposal However, Based on Limited Field Experience to Date, the Following is Recommended:

   Resin – Crush & Bury

   Catalyst – Ensure that Containers are Empty, then Crush and Bury

   Promoter – Same as Catalyst

   Solvent – Crush and Bury

   Fiberglass – Bury

Figure 26: CLEAN UP AREA – HIGH RATE SYSTEM

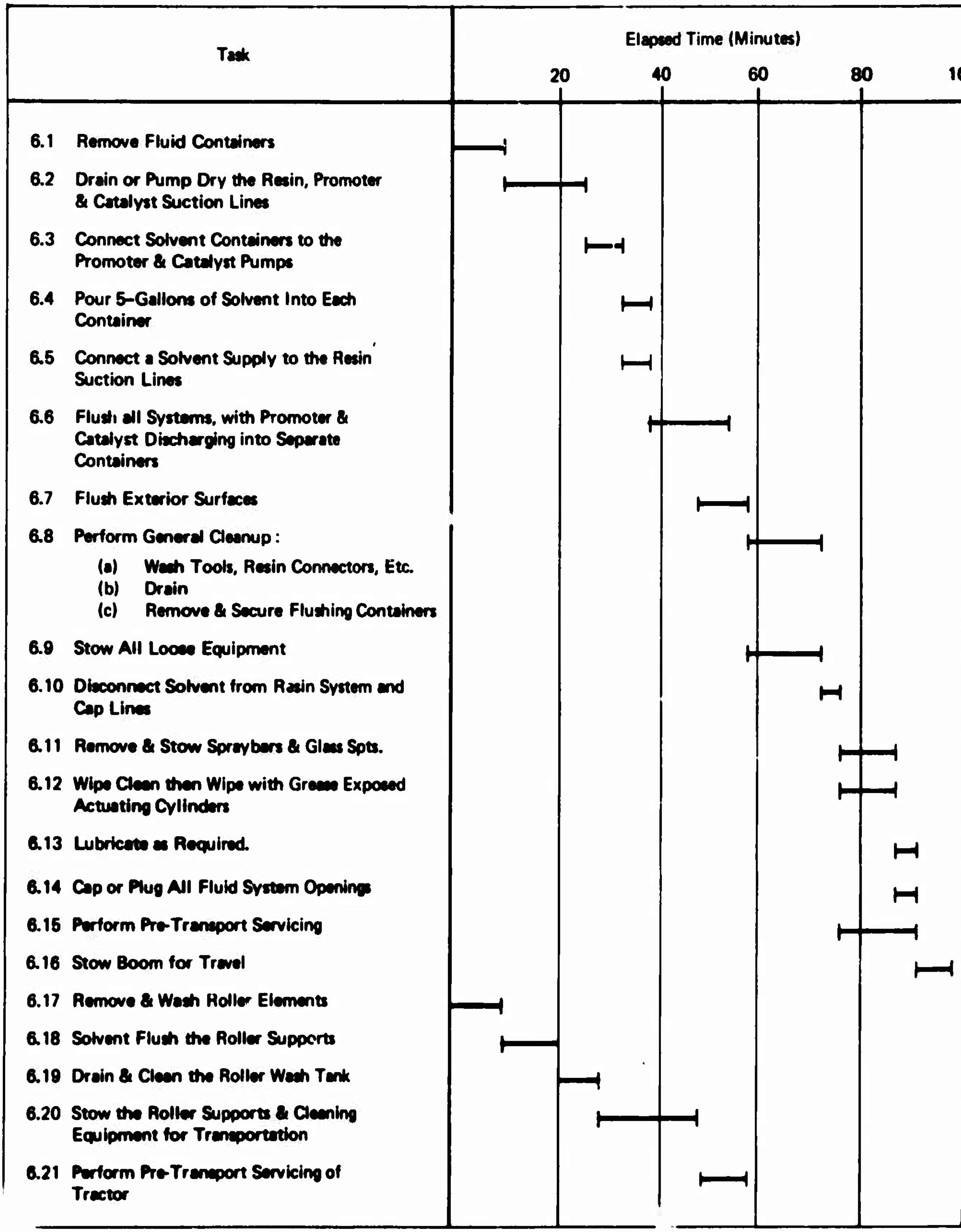


Figure 27 : PREPARE EQUIPMENT FOR TRANSPORTATION – HIGH RATE SYSTEM

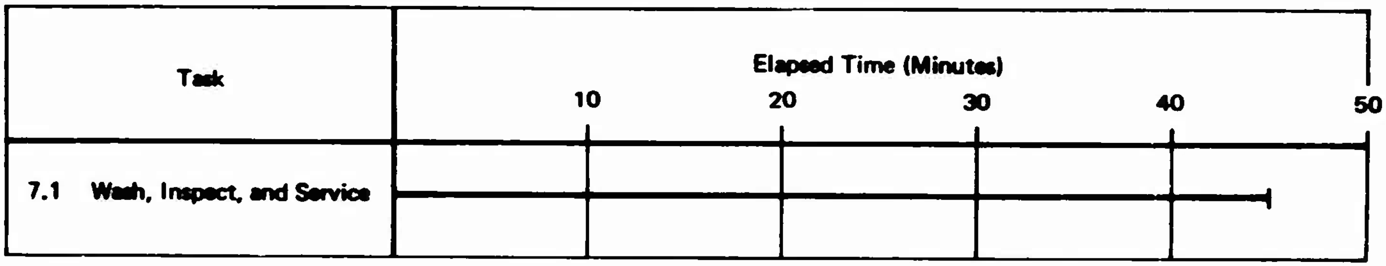


Figure 28: PREPARE EQUIPMENT FOR STORAGE – (G) SYSTEM

Table 14: PERSONNEL LIST – HIGH RATE SURFACING SYSTEM

Job Title	Code	Primary Job
Dispensing Equipment Operator	A	Controls materials application
Materials Tender	B	Ensures an adequate materials supply.
Dispensing Equipment Driver	C	Controls vehicle under direction of A or G.
Forklift Operator (2)	D1 D2	Operates forklift
Crane Operator	E	Operates crane
Roller Operator	F	Operates and cleans surfacing roller
Ground Observer (Crew Chief)	G	Provides overall direction
Materials Handler	H	Assists during glass loading and helps prepare new rolls for loading.

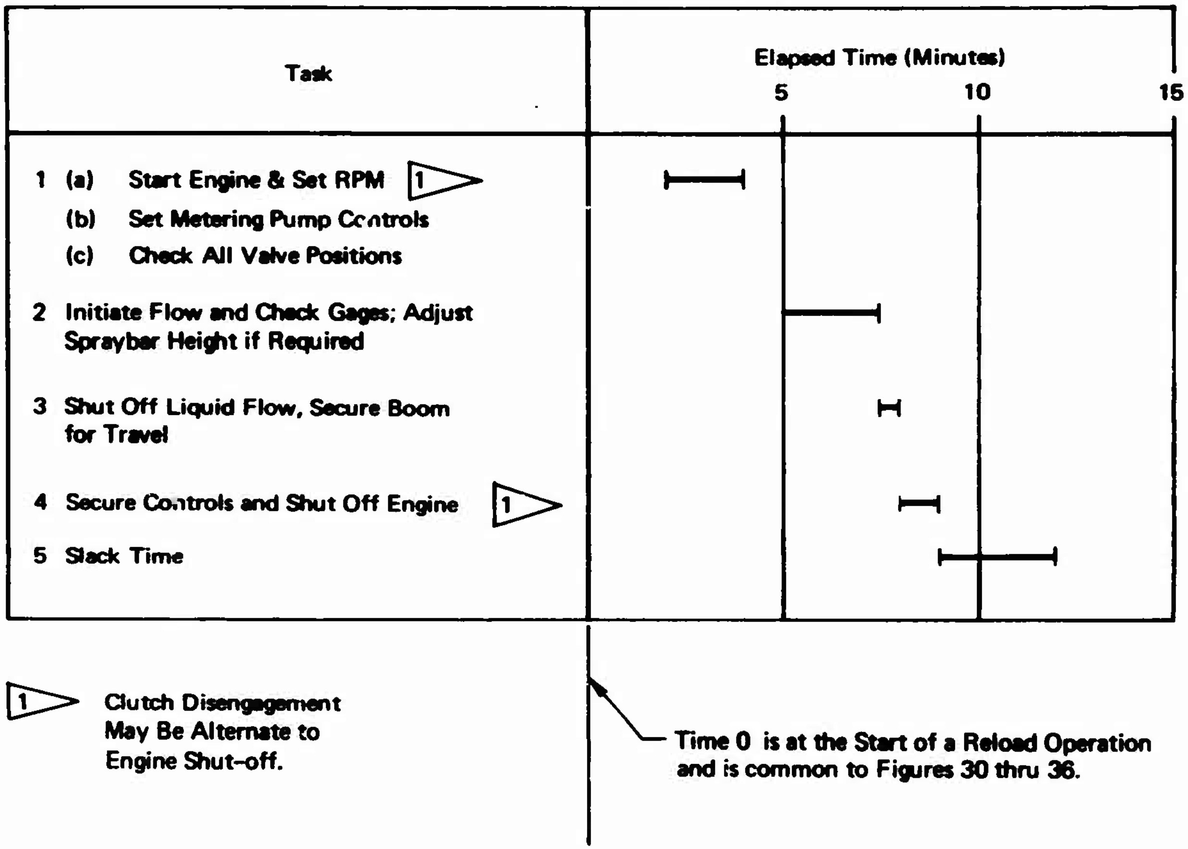


Figure 29: PERSONNEL UTILIZATION, A

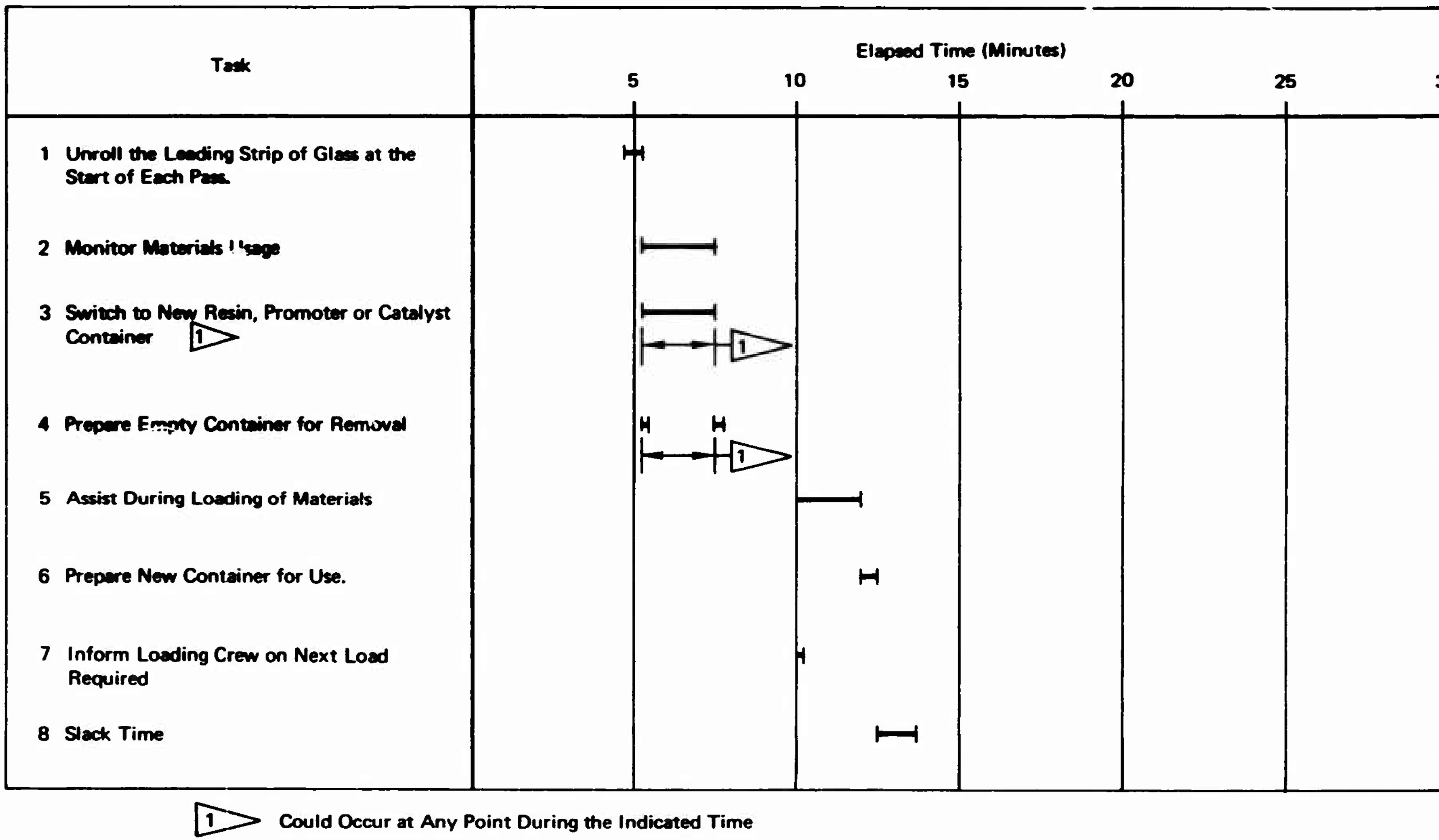


Figure 30: PERSONNEL UTILIZATION, B

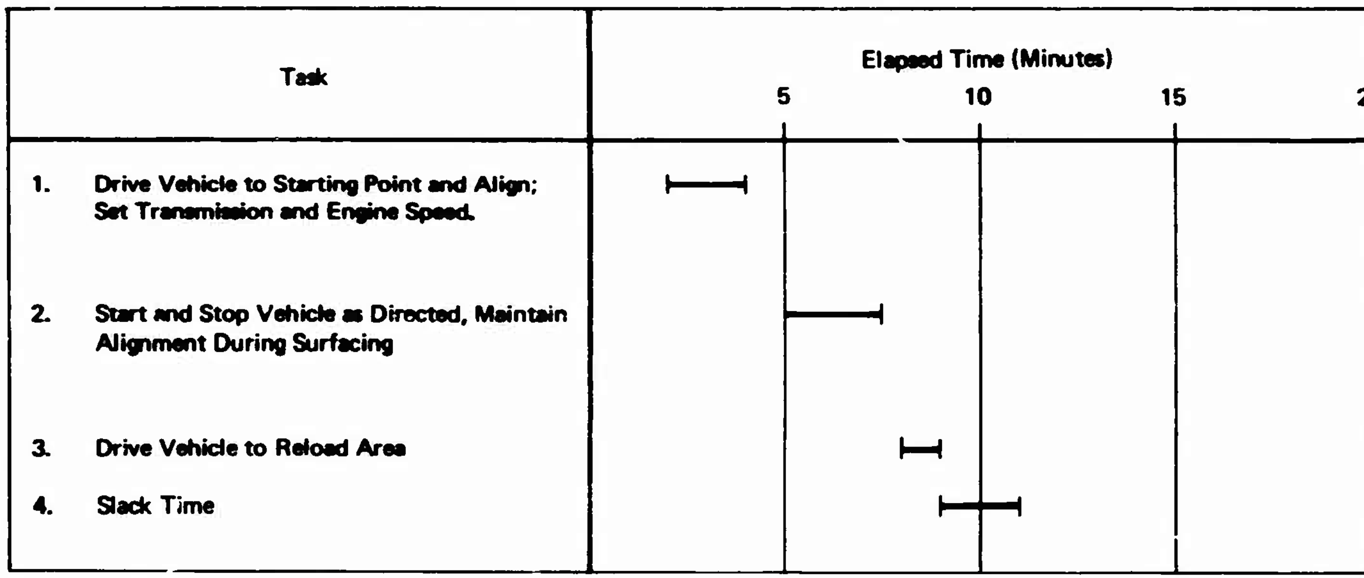


Figure 31 : PERSONNEL UTILIZATION, C

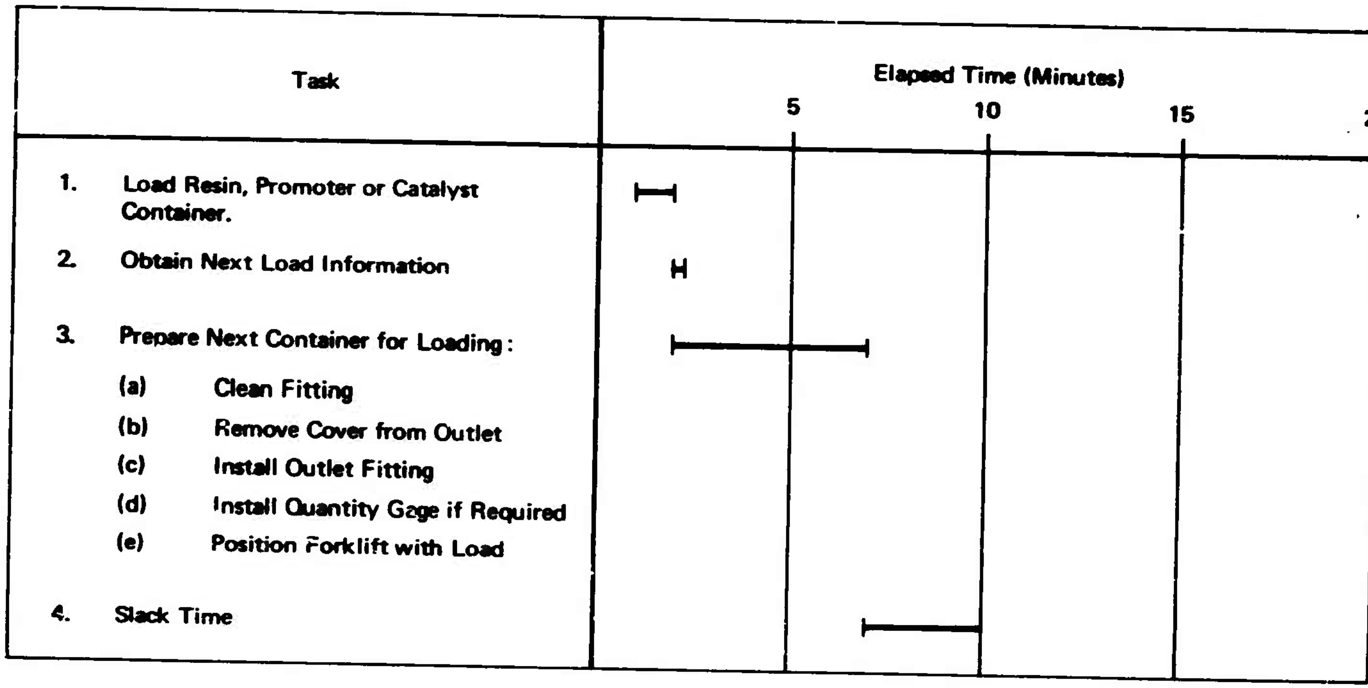


Figure 32 : PERSONNEL UTILIZATION, D1

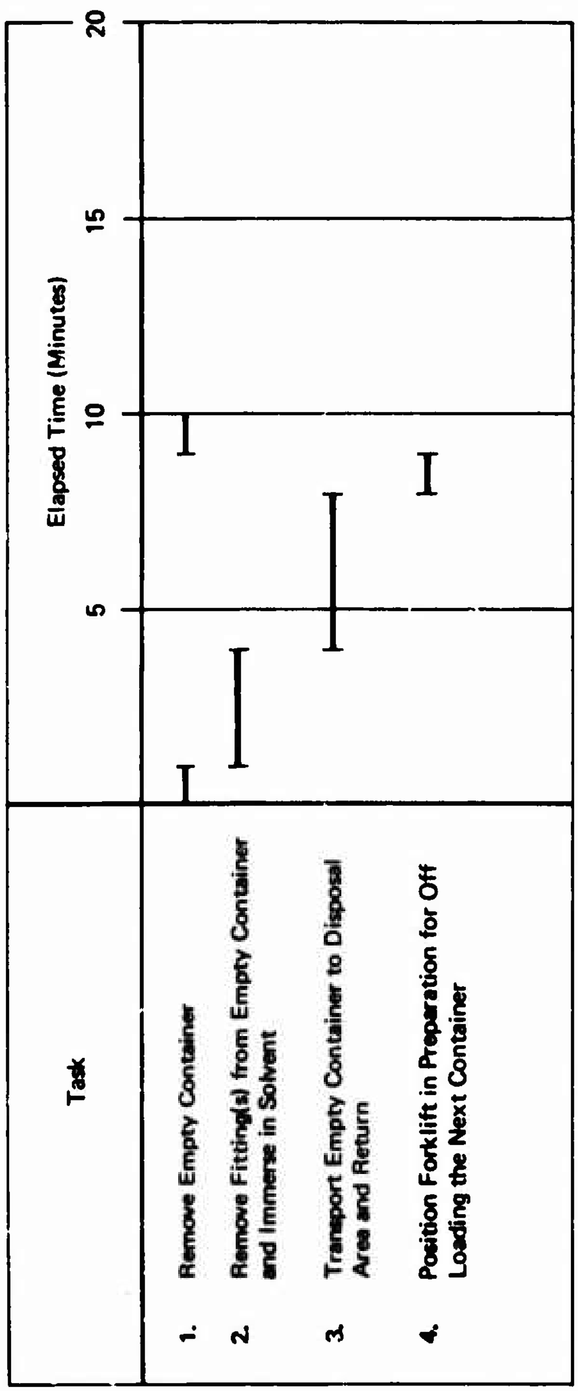


Figure 33 : PERSONNEL UTILIZATION, D2

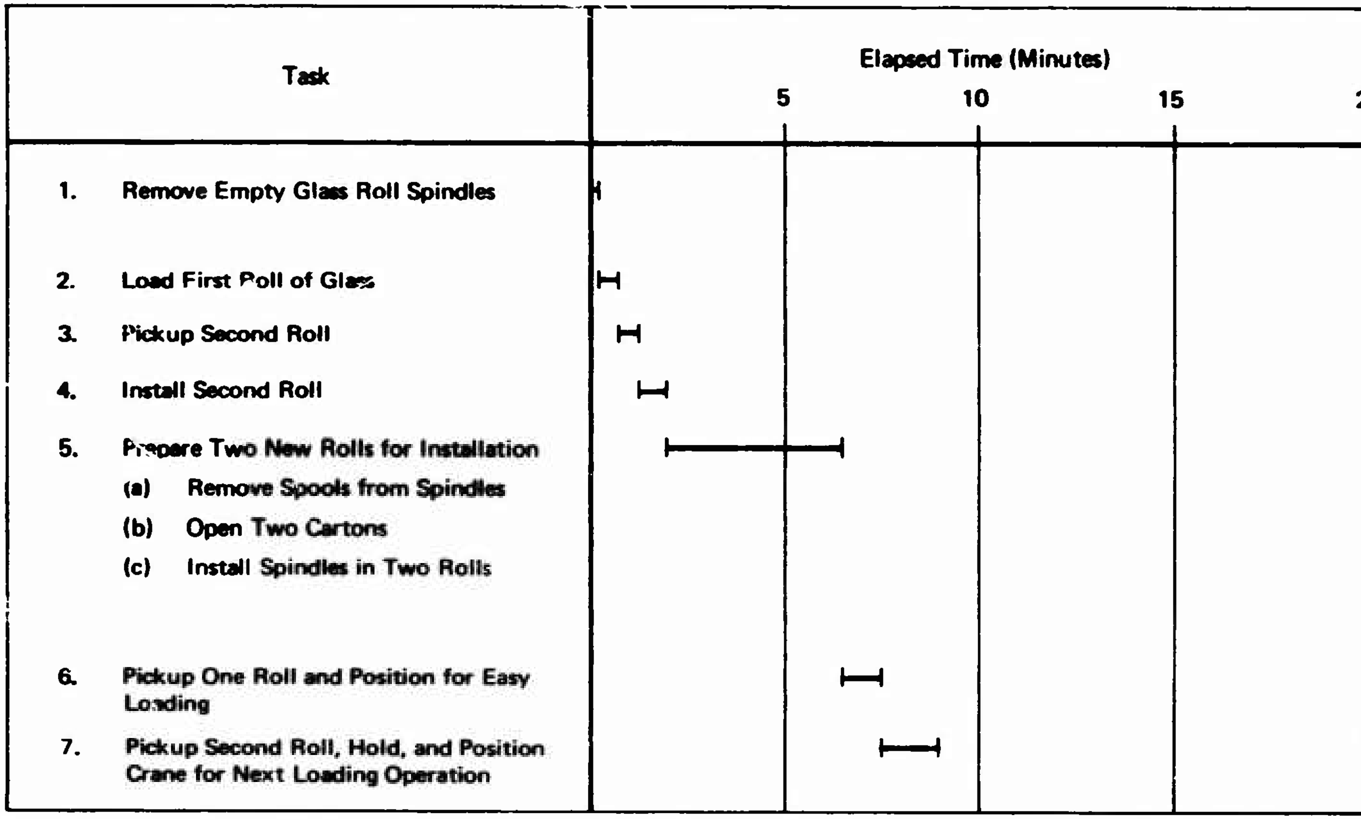


Figure 34 : PERSONNEL UTILIZATION E, H

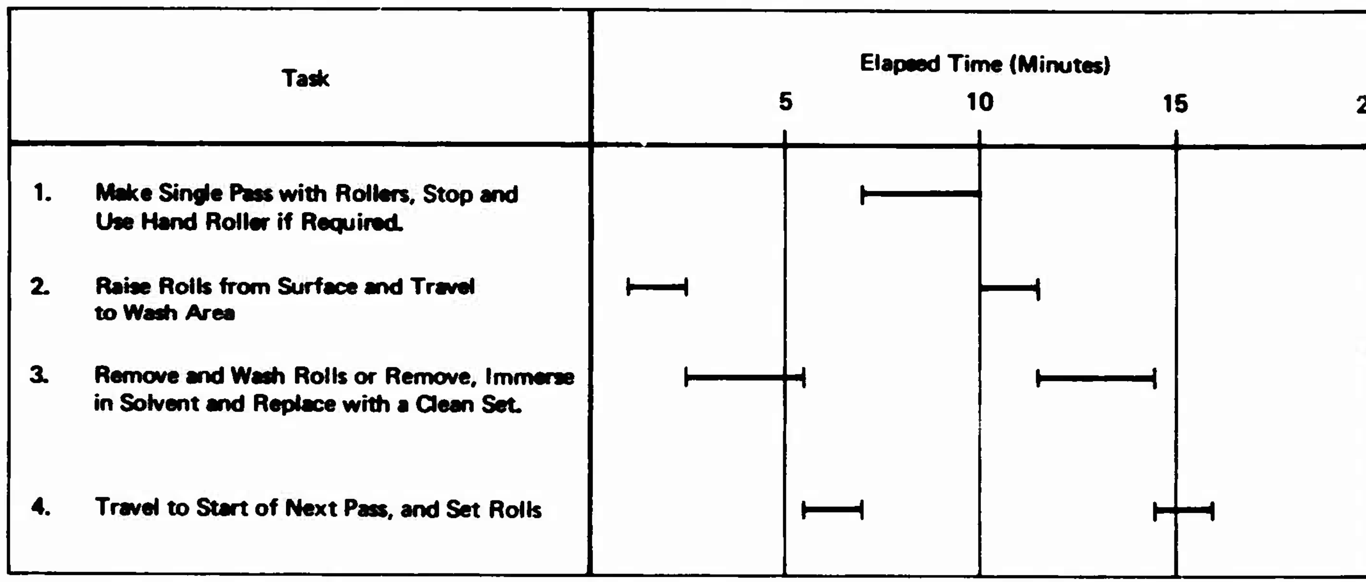


Figure 35 : PERSONNEL UTILIZATION, F

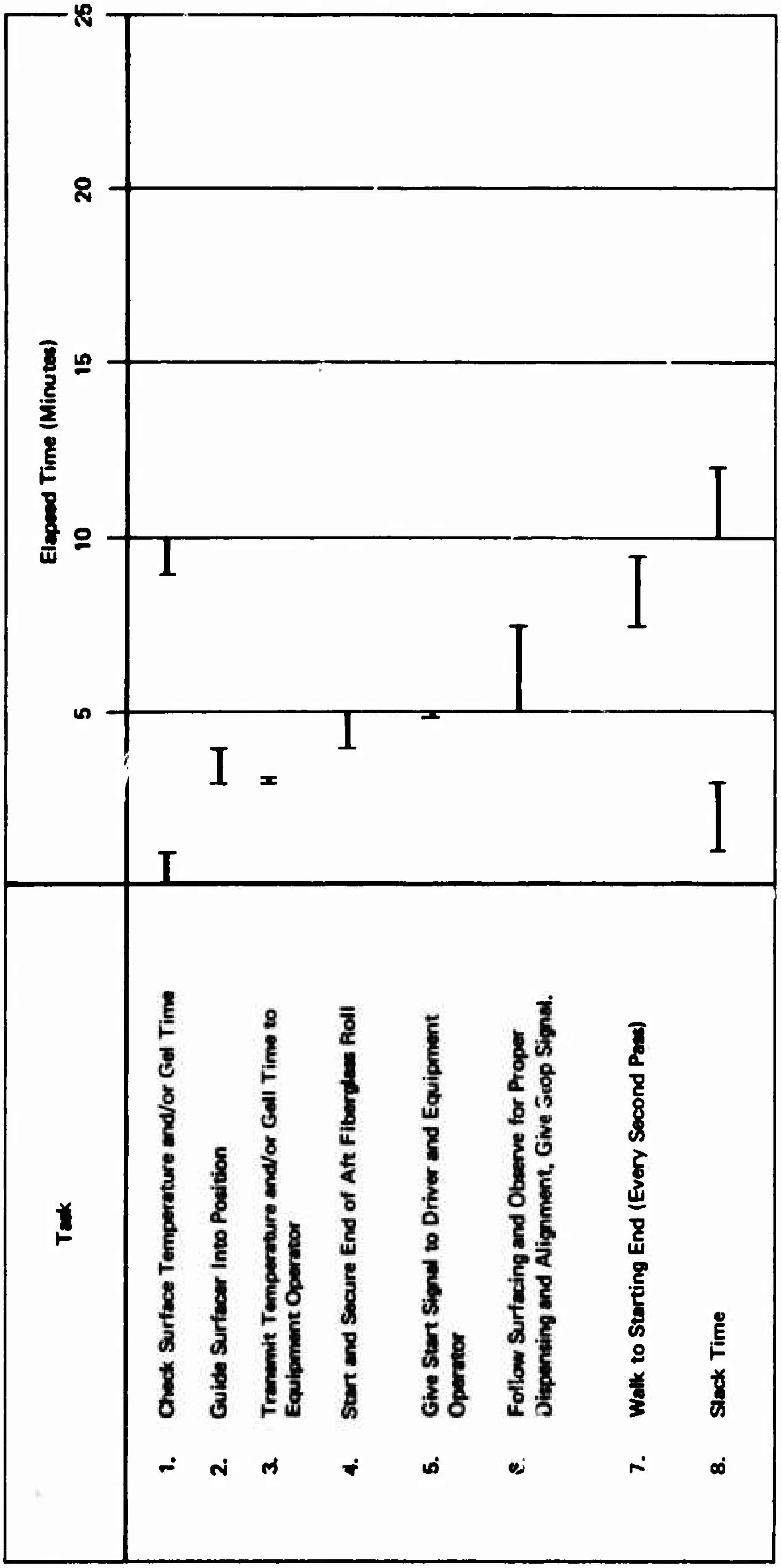


Figure 36: PERSONNEL UTILIZATION, G

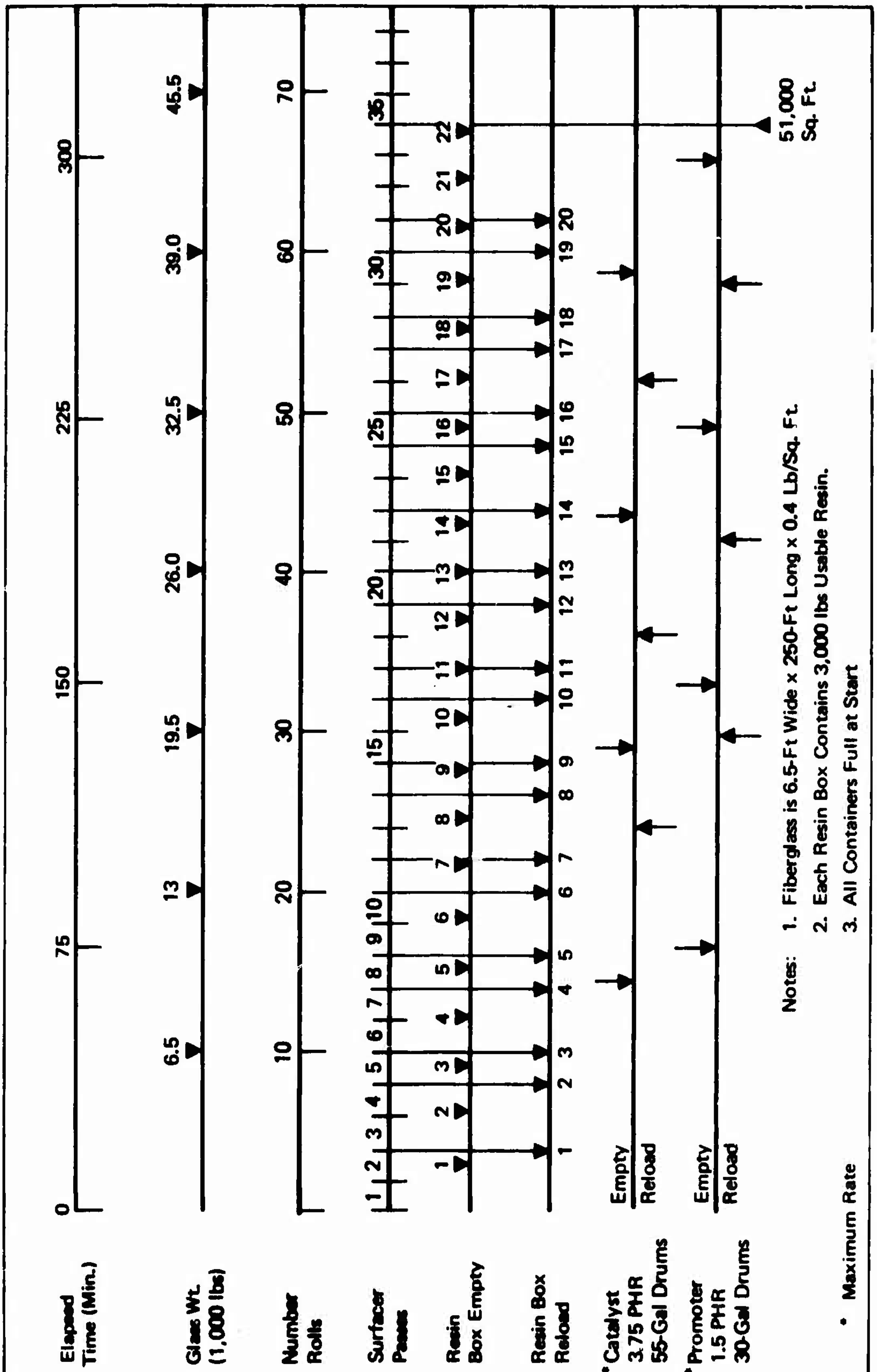


Figure 37 : MATERIALS CONSUMPTION SCHEDULE

Table 15: EQUIPMENT LIST – HIGH RATE SURFACING SYSTEM

Item	Qty	Function
High Rate Dispenser	1	Apply fiberglass and resin
Tractor, Glass Rolling	1	Transport glass roller
Glass Roller (with extra roller segments)	1	Roll wet fiberglass
Forklift, Rough Terrain 4,000 lbs Capacity	2	Materials handling
Crane, Mobile, 2,000 lb Capacity	1	Materials handling
Glass Handling Sling	1	Glass roll pickup
Glass Roll Mandrel	6	Glass roll handling and dispensing
Glass Roller Washer	1	Cleans roller between passes
Cutter, Fiberglass	1	Cuts fiberglass matting
Tool Set	1	Miscellaneous
Roller, Manual	2	Correcting trouble spots
Saw, Abrasive Gasoline Powered	1	Trimming ends and cutting joints
Drum Spigot	1	Obtain solvent from 55 gal drum for roller cleaning and general cleanup
Wash Tank for Resin & Catalyst Fittings	2	
Promoter System Solvent Tank	1	System flushing
Catalyst System Solvent Tank	1	System flushing
Paint Brushes (Assorted Sizes)	6	Cleanup
Bucket, Plastic 10 qt	6	Cleanup
Rags	As Req'd	Cleanup
Thermometer	1	Measure air or soil temperature
Glass Hold Down Tool	1	Secure glass ends at start of surfacing
Drum Handling Sling – 55 Gal.	2	
Drum Handling Sling – 30 Gal.	2	
Stakes	12	Position markers
Twine	1,000′	Equipment, initial guide
Stop Watch	1	Check gel time
Steel Tape 100′	1	
Bung Wrench	1	
Eye Wash, Portable	1	
Water Jug	1	Drinking and emergency wash
Waste Cans	As Req'd	
Mechanics Tool Set	1	Equipment setup and maintenance
Shovels	3	
Brooms	3	Cleaning joint areas
Hammer – 2 lb	1	Drive stakes
Oiler		Equipment Lubrication
Squeegee, Rubber	2	Spreading resin and working out wrinkles
Solvent Spray Hose	1	Washing exterior surfaces
Grease Gun		Equipment Lubrication
Support Materials		
1. Gasoline		
2. Motor Oil		
3. Metering Pump Oil (AGMA No. 8 Compounded, Gear Lube)		
4. Grease, General Purpose		
5. Common Motor Vehicle Materials		
6. Hydraulic Fluid		

3.3.2.2.2 Operational Analysis (Cont)

When the materials have been prepositioned and surfacing is ready to begin, final preparations are completed and surfacing commences. In order to achieve the desired rate of 10,000 sq ft/hr, a 250-foot pass must be completed each 9 minutes. The required tasks and estimated time phasing are detailed in Figure 24. As noted before, the entire crew is involved in surfacing, so edging or joint preparation cannot take place until the surfacing is completed. Expansion joints, edging, and various cleanup tasks are then performed and are shown in Figures 25 through 28.

Using the foregoing as a baseline, the following variations will be considered:

1) Smaller areas not evenly divided into the fiberglass roll length

2) Soft terrain

3) Uneven terrain

4) Operation with the boom on the right side and to the rear

5) Inclement weather

6) Varying material package size

o <u>Smaller Areas</u>--Assuming a 150-foot by 150-foot surface, the area is 22,500 square feet or 45% of the baseline area and the materials required are roughly proportional. An overall time estimate is shown in Figure 38. Materials prepositioning time is nearly proportional to the material quantities involved and equipment preparation is the same as for the baseline case. Surface application is more time consuming because of more frequent stops, the need to cut the fiberglass at the end of each pass, and the greater proportion of travel time required.

o <u>Soft Terrain</u>--Soft terrain may be expected to slow down the surfacing rate by various amounts depending on soil conditions and the method of coping with the problem. Under the worst case where the surfacing equipment must advance while travelling on previously cured surfacing and assuming that the material must cure for 1 hour before it may receive traffic, 4 passes per hour could be completed for a rate of 6,000 sq ft/hr. Because of additional travel required, slower travel due to terrain, greater difficulty in loading materials, and the increased probability of glass wrinkling, additional undeterminable reduction in output is possible under these conditions. Under more favorable conditions where the soil strength is marginal, minor delays to repair ruts or chuck holes may be the only penalty.

o Uneven Terrain--Where the area to be surfaced is of adequate strength but is uneven, two effects are anticipated:

  1) Slower travel speeds during surfacing and during travel to and from the reload area

  2) Some wrinkles requiring repair

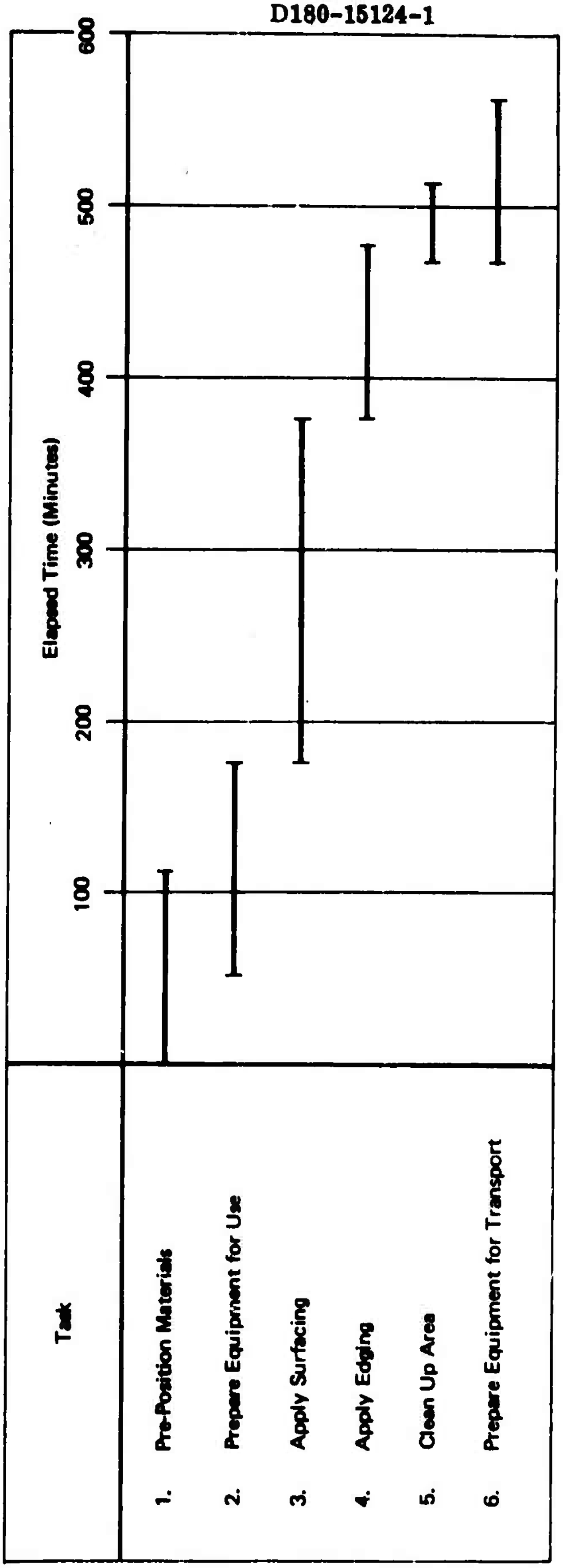


Figure 38 : CONSTRUCT 150 FT x 150 FT AREA, HIGH RATE SYSTEM

3.3.2.2.2 Operational Analysis (Cont)

Assuming that speeds are reduced to 50%, the average cycle time would increase from 9 to 14.5 minutes for an adjusted rate of 6,200 sq ft/hr. The amount of repair cannot be predicted in advance, and depends upon the number of defects as well as other intangibles such as urgency of completion and required surface quality. If a high quality load bearing surface is required, wrinkles should be cut out and patched using bucket mixed liquids with fiberglass patches cut to size and manually rolled. Care is required to ensure a clean joint. Sweeping then washing with solvent is recommended. On multilayer surfacing succeeding patching layers should be of increased size to produce a feathered edge instead of an abrupt step.

- Boom Positioning--Operation with the surfacing being applied on the driver's side of the surfacer is expected to be more convenient than when other positions of the material dispensing boom are utilized. Driver visibility is good for maintaining alignment and the actual surfacing application is visible thus reducing dependence on hand signals. Loading is also easier because the fiberglass and resin handling activities are separated to opposite sides of the vehicle.

  Though less convenient, no significant differences are foreseen when other boom positions are utilized and once the operation is familiar to the crew it should pose no problems. One probable additional task required would be positioning the boom or the dispensing head during loading. With the boom to the right side, resin and glass loading might otherwise conflict and with the boom to the rear, access for loading the forward glass roll is restricted. Any delay incurred is expected to be small.

- Inclement Weather--Based on past experience, the system is not highly sensitive to the environment. However there are limits. During extremely hot, sunny weather, care must be taken to maintain a gel time of sufficient length to prevent material from curing before or during the rolling operation. A means of keeping the catalyst temperature from exceeding 100°F is necessary. Various means of accomplishing this in the field are possible, such as rigging a cover or keeping the material containers wet. Short term heating of the catalyst to 100°F or slightly above just before or during use is not believed harmful. However material that has exceeded 100°F should not be placed back in stock.

  Decreasing temperatures cause the resin and catalyst viscosity to increase and at 36.5°F the promoter freezes. The planned system is satisfactory at 40°F, however at significantly lower temperatures degradation of operation can be expected. The catalyst and promoter metering pump oil requires dilution at temperatures below 60°F but is operational to -25°F. The net result is that the equipment with some special care is operative in cold weather.

3.3.2.2.2 Operational Analysis (Cont)

When surfacing is applied during ambient temperatures below $40^{o}F$ the cure time can be expected to exceed 1 hour. Though the quality of the finished surface is expected to be satisfactory, no field investigation of these conditions has been accomplished. The surfacing can be applied during rainy or windy weather. However, the fiberglass should be kept covered until it is applied. Operation during heavy rain should generally be avoided. Although the precise effects are not known, degraded surface appearance and possibly reduction in material properties appears likely.

o Material Modules--The fiberglass, resin, catalyst, and promoter packages should be sized to provide the largest possible surfacing area between reloads within reasonable handling sizes, and as far as practicable, minimize the downtime to reload.

Varying the width, length or unit weight of the fiberglass affects various elements of the system. Tentative maximum length and weight that fiberglass manufacturers can furnish is 250 feet at .4 lb/sq ft. Accepting these limits leaves the choice of width open. The width affects the application geometry with wider glass causing proportionally more excursion at the outer end of the fiberglass roll resulting in a greater tendency to wrinkle. The truck lateral tipping moment and roll inertia is also affected. The efficiency of application and use is better with wider fiberglass because of the proportion of material handling effort and material overlap in relation to the quantity of material applied is reduced. Manufacturers can currently supply any width up to 13 feet.

Most 2-1/2 ton and larger trucks and trailers will accommodate 7 foot wide rolls across the bed; thus handling and transporting this width or less would be somewhat easier. Air transport via C-130 will accommodate widths to 9 feet without the need for end loading. Final selection of the best glass width to achieve 10,000 sq ft/hr is subject to continued design studies. However 6.5 to 8 feet appears to be the most likely boundaries.

The resin container size currently used with the On-Fast system is 315 gallons and is the tallest container that can be economically fabricated from standard size plywood. There is no significant advantage to reducing this size, since the package is readily handled with forklifts of 2 tons or more capacity. A single container is sufficient to exceed the requirements of the largest conceivable single charge of glass. Therefore not more than on resin container need be replaced during a fiberglass replenishment stop. The next significant point on increasing size would be to provide the capability to cover two loads of glass with a single container and would require approximately 4,800 pounds of resin for 8 feet by 250 feet fiberglass or 3,900 pounds for 6.5 foot fiberglass. This would permit alternate unloading of empties and loading of full resin containers with a single forklift during glass reloading stops. In view of the development necessary to increase the size, the adequacy of the current packaging, it is considered that changes requiring extensive redesign should not be attempted. The possibility of modifying the container plan form to 48 by 48 inches instead of the current 40 by 48 inches will be considered however. This would bring the capacity to approximately that required for two passes with 6.5 foot fiberglass and would reduce the effort required to handle resin containers.

3.3.2.2.2 Operational Analysis (Cont)

Table 16 presents a comparison of three containerization methods considered for promoter and catalyst. The selected container sizes must be compatible with the loading equipment and procedures. For Method A and B where manual handling is required, 5 gallon containers are as big as can be conveniently handled. By going to larger containers, Method C, which requires equipment for handling, and using the same concept as the resin tankage, where two containers are utilized in series, more efficient use of manpower is possible and safety is improved with less chance of inadvertent spillage of materials. With catalyst containers of 55 gallon size and promoter containers 30 gallons, replacement of empty containers can be phased into the operation to occur when a resin container change is not required during a reloading stop. This is shown on the materials consumption schedule, Figure 37. Catalyst and promoter container sizes of 55 and 30 gallons respectively should be considered with provisions on the high rate surfacer to draw from either container of each material.

A summary of the maximum material weight required on the surfacing vehicle including two containers each of catalyst, promoter, and resin and two rolls of fiberglass is as follows:

Material		Packaging	Total
Resin, 2 @ 3,000 pounds	6,000	540	6,540
Catalyst, 2 @ 55 gallons	1,080	140	1,220
Promoter, 2 @ 30 gallons	480	60	540
Solvent, 1 @ 55 gallons	600	70	670
Fiberglass, 2 rolls 8 ft x 250 ft x .4 psf	1,600	--	1,600
			10,570 lbs

Sufficient payload capability space is required for carrying the above materials along with the necessary dispensing equipment and operating personnel.

3.3.2.3 Low Rate System

In order to analyze the low rate surfacing system a rectangular area 100 feet by 120 feet composed of 2 lbs/sq ft 2 layer surfacing was selected. This size corresponds with the 6-hour continuous area of 12,000 square feet and is a likely size for a parking pad or small helicopter pad.

Table 16: COMPARISON OF PROMOTER AND CATALYST CONTAINERS

METHOD A: Pump supply hoppers whose level is maintained by manually pouring 5-gallon containers as needed.

Advantages	Disadvantages
1. No ancillary equipment is required for handling promoter or catalyst.	1. Containers must be small, therefore frequency of handling is high, approximately 4.2 GPM maximum combined rate.
2. No fluid system disconnects are required during operation.	2. The possibility of inadvertent spillage is believed great.
3. Fluid quantity indication could be a part of the fixed container.	3. Special containers would have to be developed for easy catalyst mixing and emptying and foolproofing against interchanging catalyst and promoter. This adds to cost and development time.

METHOD B: Twin special containers manifolded and used in series. Sized for manual handling and replaced as they are emptied.

1. No handling equipment is required for catalyst and promoter.	1. The disadvantages cited against Method A above are applicable.
2. The hopper is eliminated thus simplifying the system.	2. Close surveillance of the material quantity is required since there is no reservoir.

METHOD C: Twin standard containers manifolded and used in series. Sized for handling with powered equipment. Replaced as they are emptied.

1. Powered equipment is already required for resin and fiberglass. Promoter and catalyst do not require additional powered equipment.	1. A means of determining the quantity remaining in each container must be developed.
2. Containers are available, cost and development are minimal.	2. In the event a container is spilled or dropped the consequences are more severe because of the quantity involved.
3. Personnel are universally familiar with handling and use of standard drums.	3. Drum handling equipment is required for promoter and catalyst.
4. Handling frequency and personnel fatigue is reduced.	4. Small jobs during warm weather will require less than a full container. The remaining catalyst may be exposed to contamination or temperature extremes that could render it unusable.

3.3.2.3.1 General

The selected area is assumed to be level and of sufficient strength to allow operation of the surfacing and ancillary equipment. Assuming edge traffic, a three foot buried edge in accordance with Figure 15, Method 1 is included and an edge anchoring ditch is prepared along 3 edges before surfacing starts. The method of applying 2 lb/sq ft is to apply two layers and to lap each strip by 50% plus 6 inches.

Fiberglass rolls are 6.5 feet wide by 50 feet long by .4 lb/sq ft, weighing 130 pounds each, thus rolls may be easily handled by two men. Resin containers are the same as the high rate baseline, 3,000 pounds net. Promoter and catalyst are assumed to be packaged in standard drums of 30 and 55 gallons respectively. These sizes are compatible with the recommended containers for the high rate system. By standardizing containers for the two systems the logistics burden is reduced, personnel training is simplified and commonality of handling equipment is improved.

Except at temperatures near $40^{\circ}F$ the entire surface can be finished with single catalyst and promoter containers. For study purposes, the promoter and catalyst quantities consumed are 1 PHR promoter and 2.5 PHR catalyst emulsion. Total materials required are summarized in Table 17 and are based on a nominal 60:40 resin to fiberglass ratio.

The low rate dispensing equipment configuration is shown in Figure 39. Two resin containers are mounted on the trailer and used in series to minimize the disruption when a container is emptied. Because of the infrequency of emptying the promoter and catalyst containers, single containers are provided. The arrangement shown provides sufficient operating space to monitor and replace materials, observe equipment operation, actuate the metering pump and engine controls and observe the surfacing operation.

With a maximum quantity of materials on the trailer the total operational payload is approximately 10,500 pounds. The bed size required to accommodate the materials and spray unit as well as ancillary equipment storage is approximately 8 feet wide by 20 feet long. A four-wheel trailer is desirable so that it may be readily moved during sufacing without the need to deploy a landing gear. Other requirements and capabilities of the trailer are contained in Section 3.4.4.

3.3.2.3.2 Operational Analysis

The operational analysis of the low rate system was accomplished similar to that of the high rate system. Materials are assumed to be trucked to the site on two semitrailers in the following packages:

o <u>Fiberglass</u>--Throwaway spool, plastic moisture barrier wrapper, cardboard container, 9 rolls per pallet, 130 pounds per roll

<u>Resin</u>--Individual 3,000 pound containers with forklift base

o <u>Solvent & Catalyst</u>--55 gallon drums, pallestized

o <u>Promoter</u>--30 gallon drums, loose

Table 17: ***MATERIALS REQUIRED FOR 100 FT x 120 FT SURFACE***

Required Usable Area :	12,000 sq ft (See Figure 4)
Surfacing Weight :	2 lb/sq ft
Reinforcement :	6.5 ft wide x 50 ft long x 0.4 lb/sq ft
Total Width & Length with Edging :	106 ft x 120 ft

With 6-inch laps, effective width per strip is 3.0 ft; then $\frac{126\ \text{ft/width}}{3\ \text{ft/strip}} = 42$ strips. With one additional strip along each parallel edge, 44 full length strips are required. Two edge strips are also required along one edge running perpendicular to the pad strips. The total fiberglass requirements then are 44 x 100 ft + 2 x 120 ft = 4,640 ft or 93 rolls at 50 ft per roll.

Liquid requires is $\frac{60}{40}$ x 4,640 ft x 6.5 ft x 0.4 lb/sq ft = 18,096 lbs total liquids*

*Liquid composition is 100 parts resin + 2.5 parts catalyst + 1.0 part promoter

Resin at 100 PHR = 17,481 lbs = 5.8 or 6 containers.

Catalyst emulsion at 2.5 PHR = 437 lbs = 44.6 gallons or one container at 55 gallons each.

Promoter at 1 PHR = 175 lbs = 21.9 gallons or one container at 30 gallons each.

Solvent : One cleanup at 1/2 drum plus roller washing at 1/2 drum = 1 drum.

With allowance for less than 100% utilization and possible greater than nominal usage the totals transported to the site should include :

Fiberglass	97 Rolls	=	12,600 lbs.
Resin	7 containers	=	21,000 lbs
Catalyst	1 container	=	540 lbs
Promoter	1 container	=	240 lbs
Solvent	2 drums @ 600 lbs	=	1,200 lbs

Total material weight including 10% for packaging is 39,200 lbs.

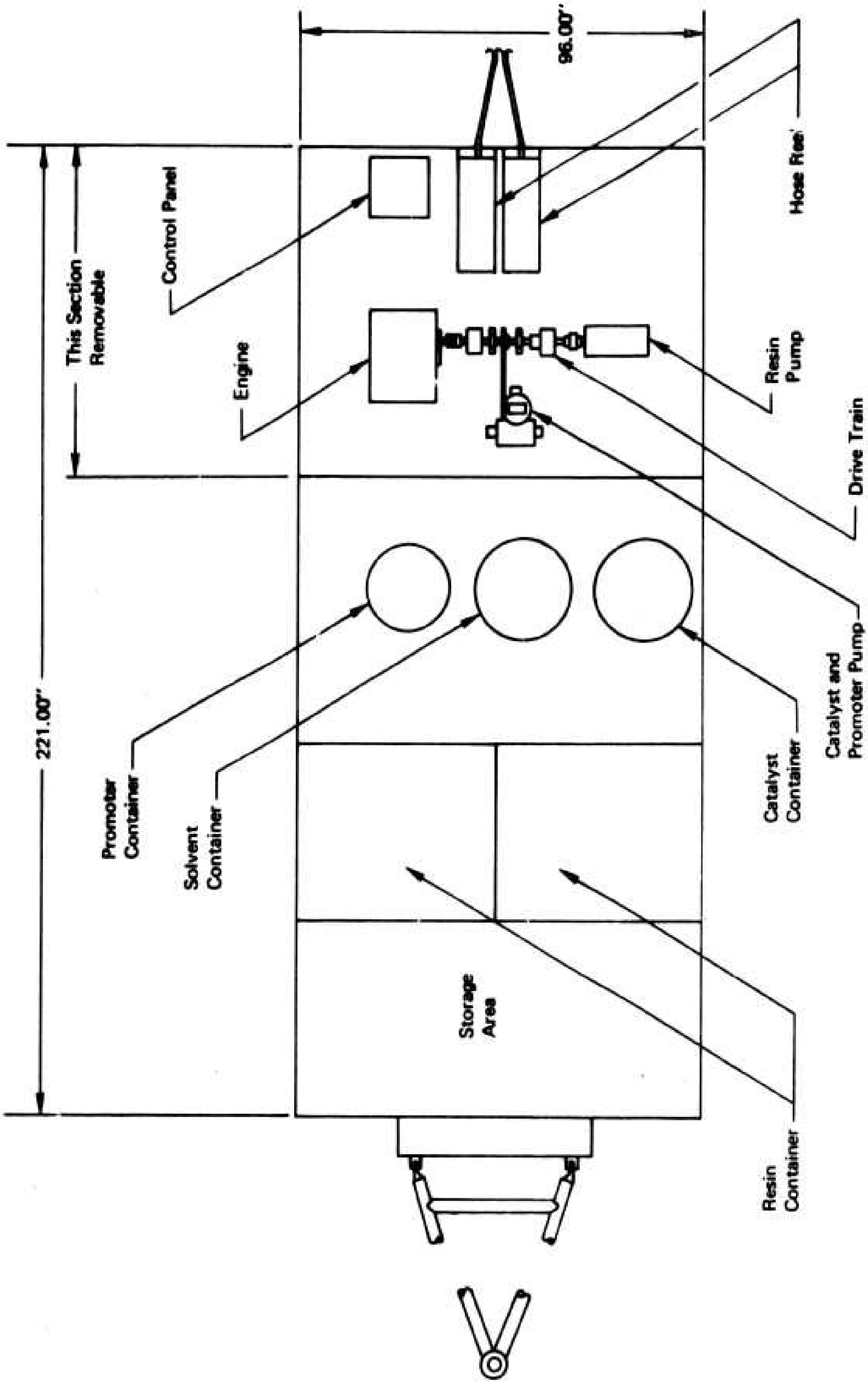


Figure 39: LOW RATE DISPENSING EQUIPMENT ARRANGEMENT

3.3.2.3.2 Operational Analysis (Cont)

The tasks required to construct the 100 ft x 120 ft rectangular area were analyzed, starting with the task of prepositioning materials at the site. The selected arrangement of materials and equipment at the site is shown in Figure 4.

Gross tasks are displayed on an overall time line in Figure 40. Each gross task is treated in greater detail in Figures 41 through 47.

Personnel are identified in Table 18, along with their respective primary functions. Figure 48 shows the specific duties of each man during the surfacing operation and illustrates a typical repeatable cycle. The required equipment is listed in Table 19. The general procedures assumed to be employed are as follows:

During site preparation three edges of the area are ditched and the area to be surfaced is levelled. As an alternate, though not recommended, all four edges could be ditched before surfacing but would result in some inconvenience during forklift travel over the edge. Fiberglass in 50 ft rolls is applied, sprayed, and rolled from right to left with the right end of the fiberglass in the right side ditch. The first two strips are laid with a 100% lap to ensure a full thickness to the edge and with one edge applied from right to left with a 3-1/2 ft overlap. The equipment must be moved at approximately each 10 strips. This is done using the forklift as a tow vehicle. Surfacing continues until the full 50 ft x 120 ft section is completed except for the final edge strip. The equipment is then moved into position to construct the second half of the surface. It is constructed in a similar manner starting with a 6 inch lap of the previously applied surfacing at the right end. The starting end of each roll should have the corner folded over to allow prewetting, then replaced flat by the spraybar operator. The second half of the surfacing is completed to the point where the equipment is moved off the surfacing area. The ditch is then constructed for the final edge and the surfacing completed including construction of the left edge and final edge. Backfilling and cleanup is then accomplished.

Figure 40 shows a method of phasing together the various major tasks and indicates that the total time from positioning materials to completion of cleanup is 11.0 hours. The prepositioning of materials and preparation of equipment occur simultaneously. As with the high rate system, during surfacing all assigned personnel are busy, therefore other tasks may not be performed. The edging of two sides is not done in the course of applying the main surfacing area but is completed as soon as possible and the equipment cleanup is started as soon as the edge surfacing is completed. Preparation for storage is done at the storage site.

Materials prepositioning (Figure 41) employs three men and a forklift. The most time consuming task is positioning the fiberglass along both edges of the surface. Liquid materials are offloaded near the area to be surfaced where they may be conveniently handled during preparation for use. While materials are being offloaded, two men are readying the equipment.

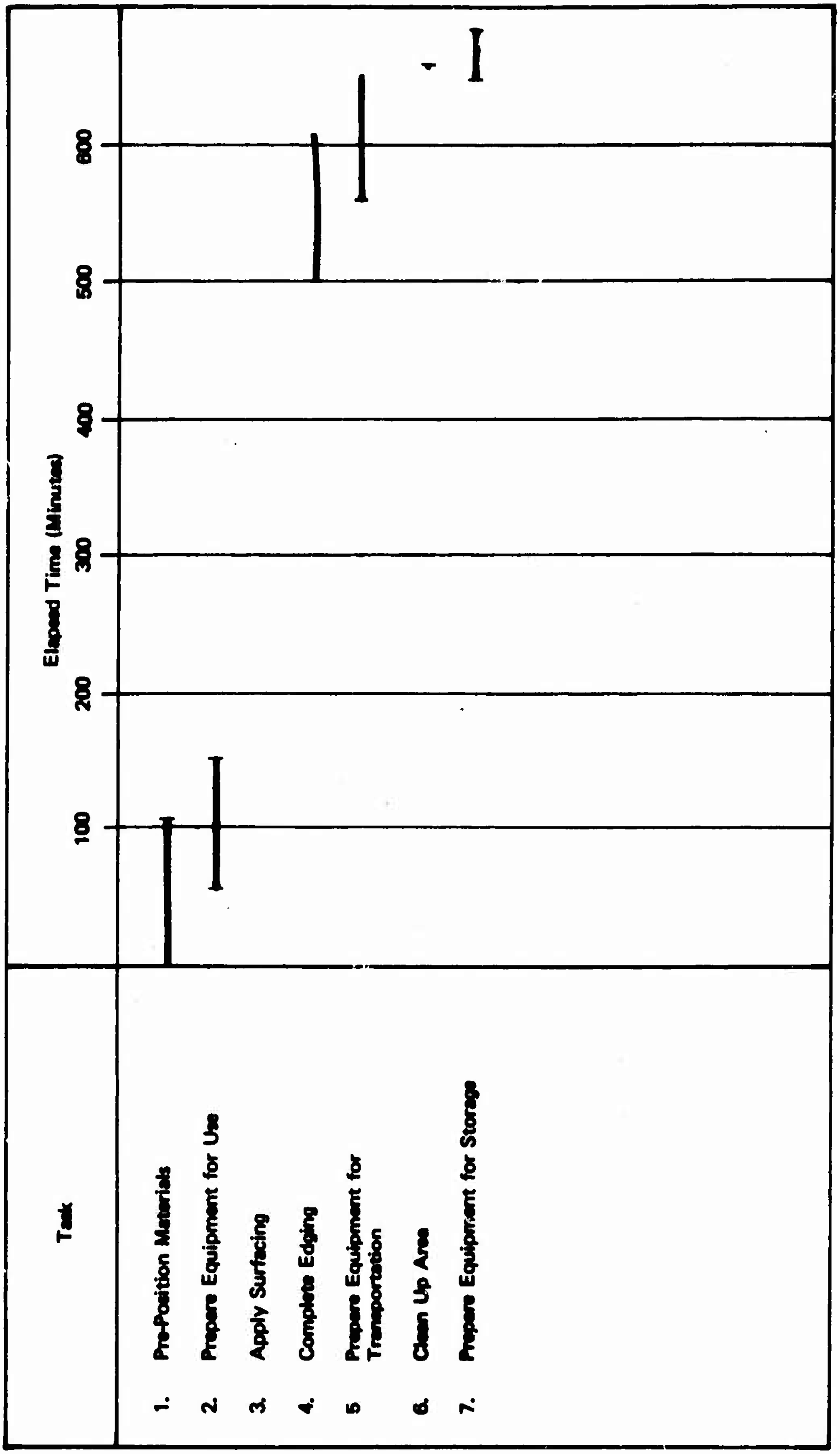


Figure 40: CONSTRUCT 100 FT x 120 FT SURFACE – LOW RATE SYSTEM

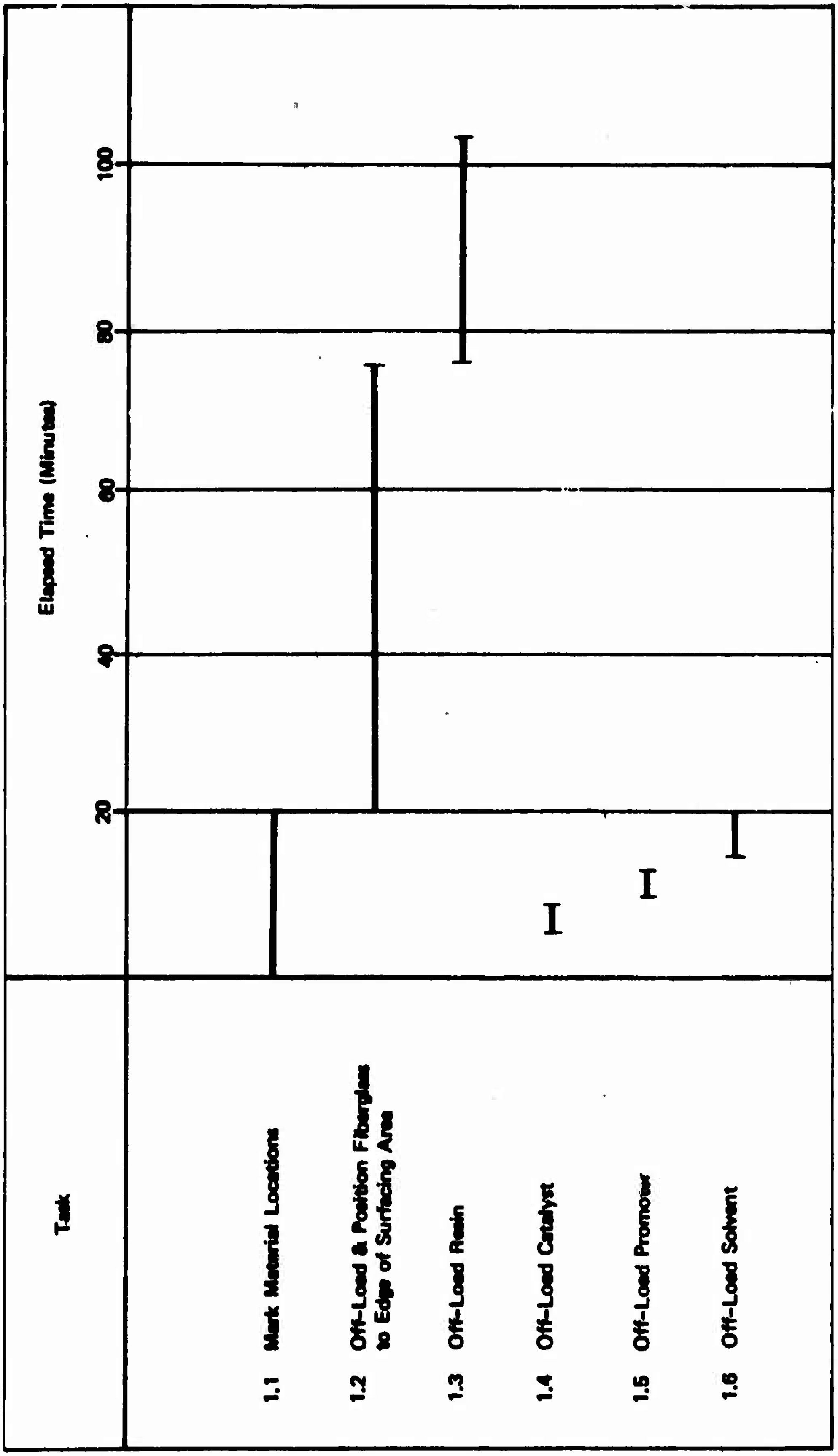


Figure 41: ***PRE-POSITION MATERIALS – LOW RATE SYSTEM***

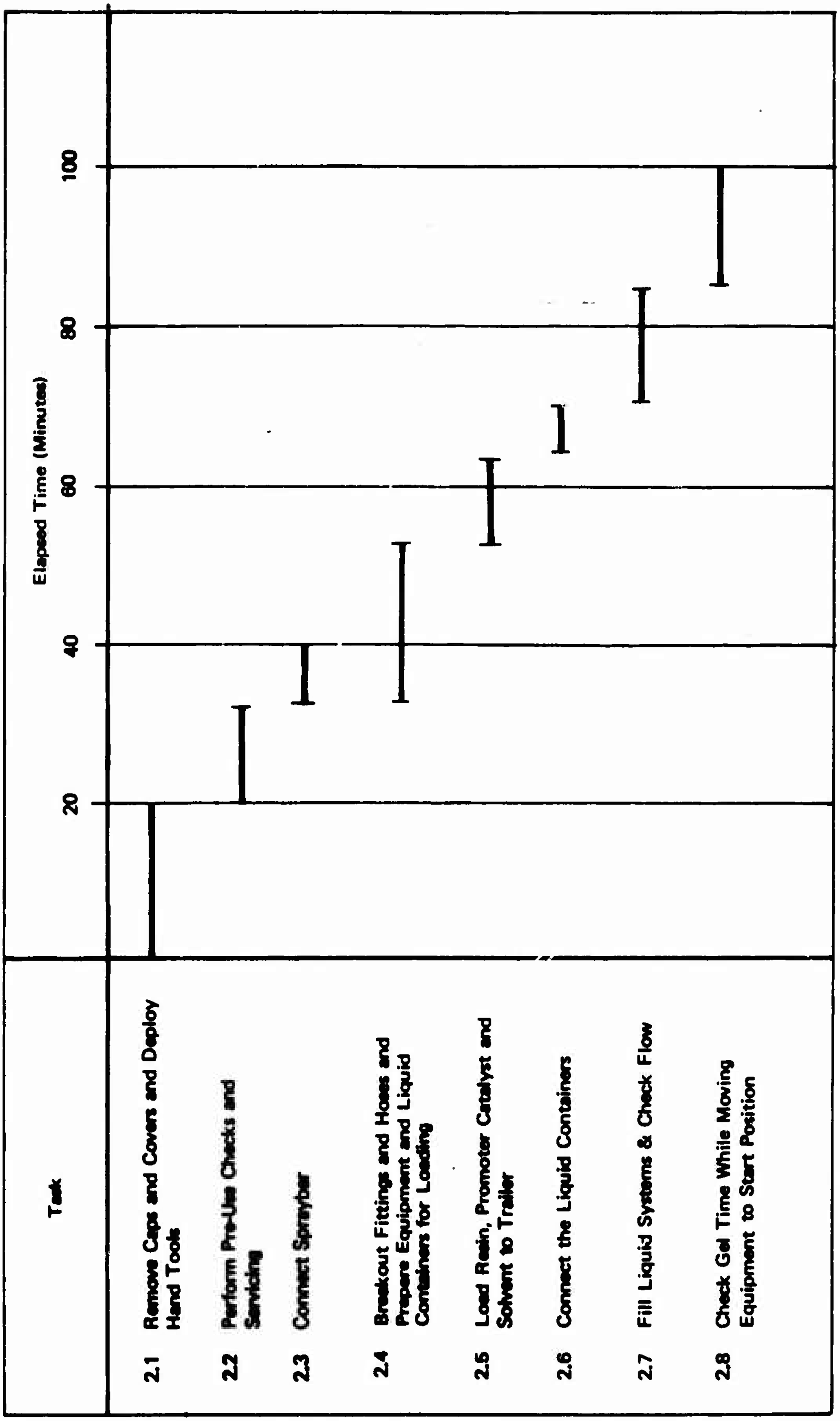


Figure 42: PREPARE EQUIPMENT FOR USE — LOW RATE SYSTEM

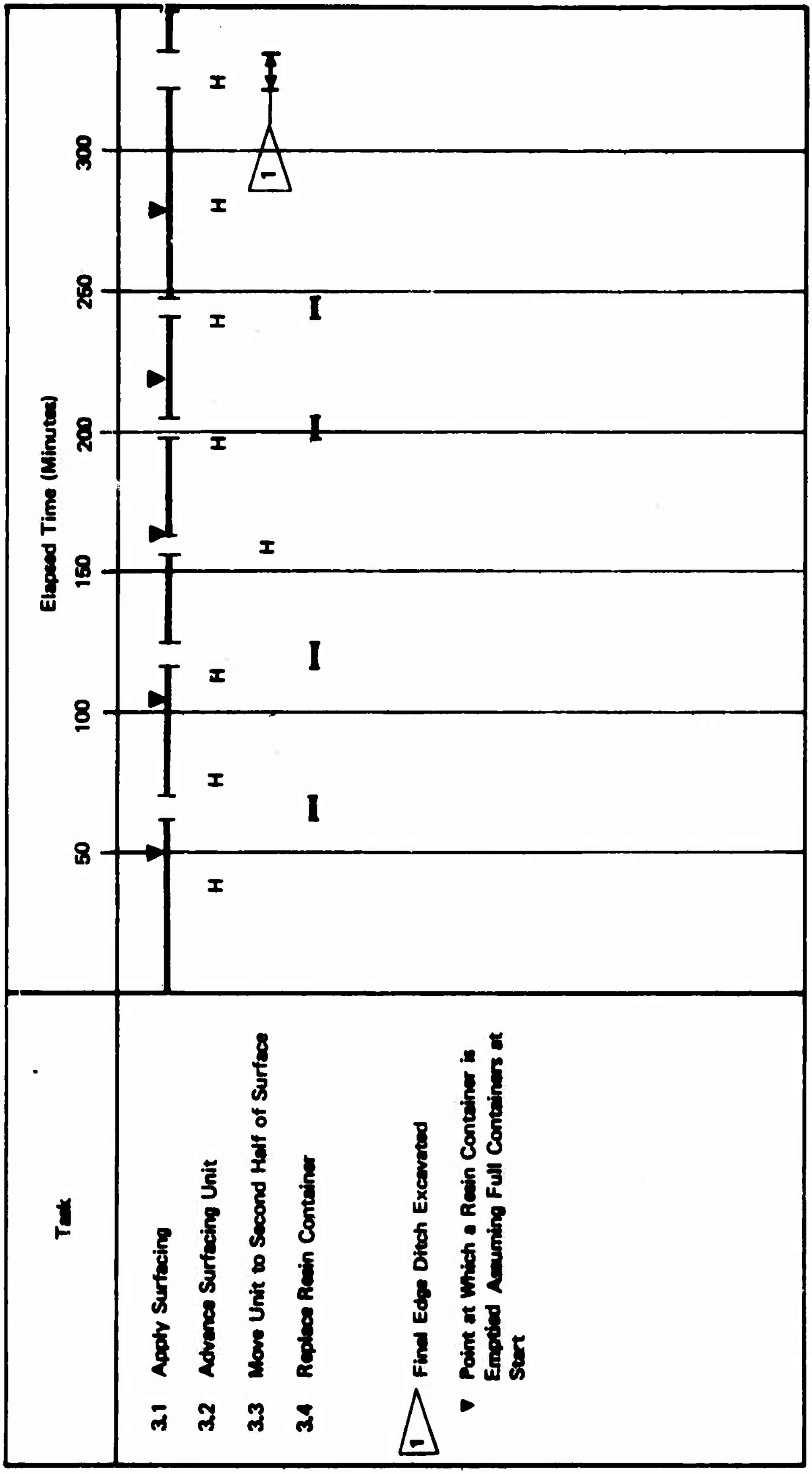


Figure 43: APPLY SURFACING – LOW RATE SYSTEM

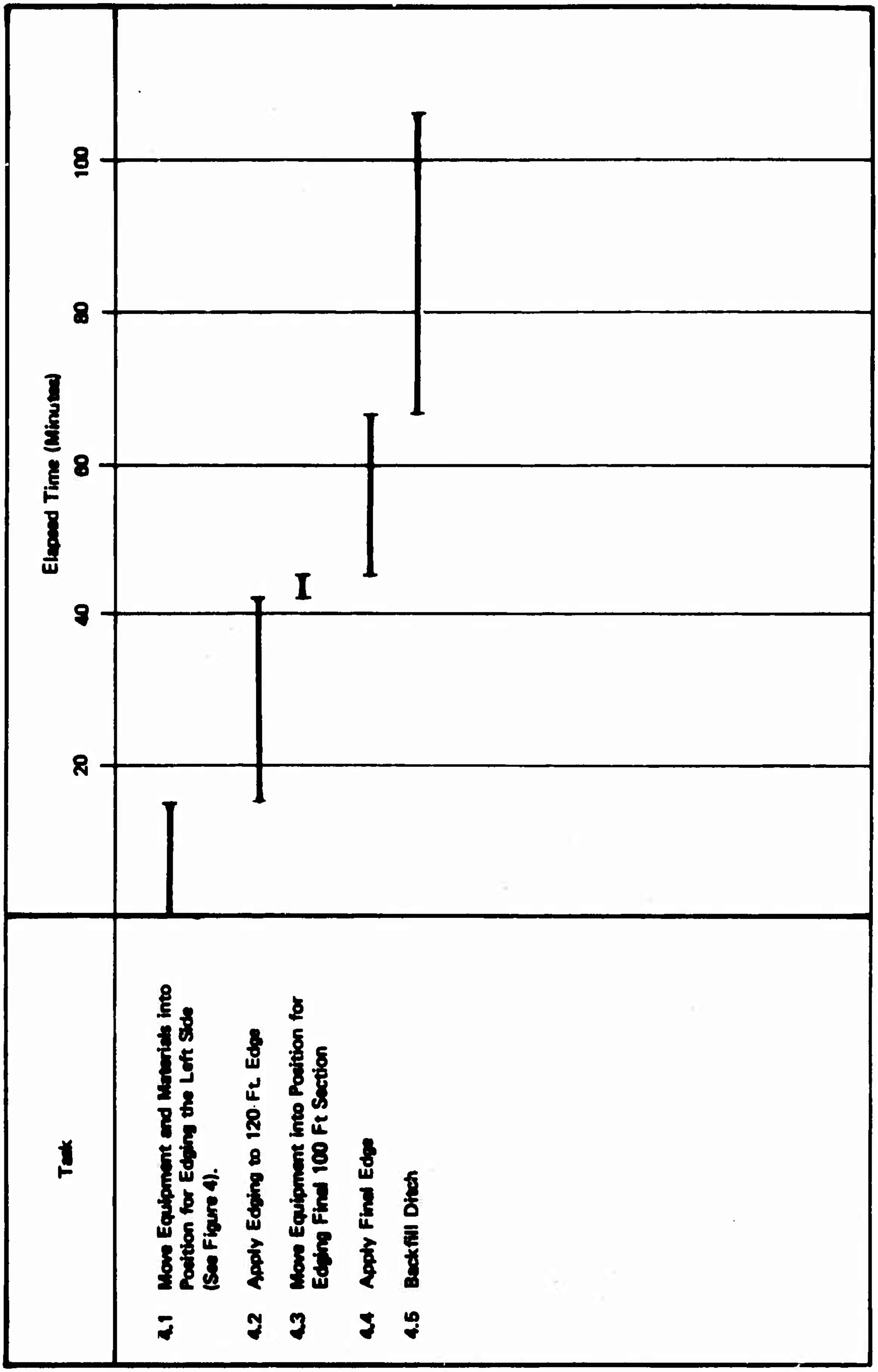


Figure 44: *COMPLETE EDGING – LOW RATE SYSTEM*

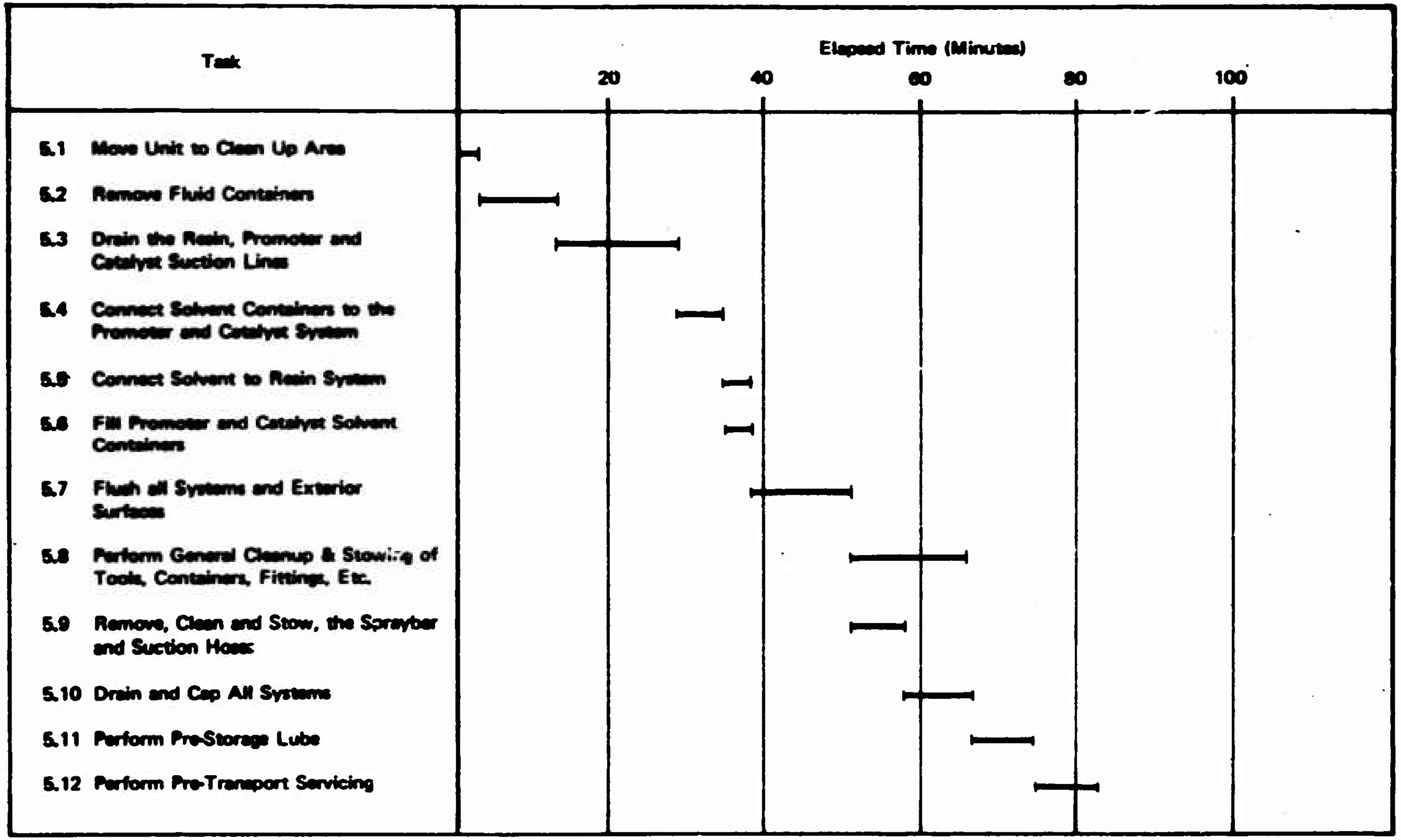


Figure 45: ***PREPARE EQUIPMENT FOR TRANSPORTATION – LOW RATE SYSTEM***

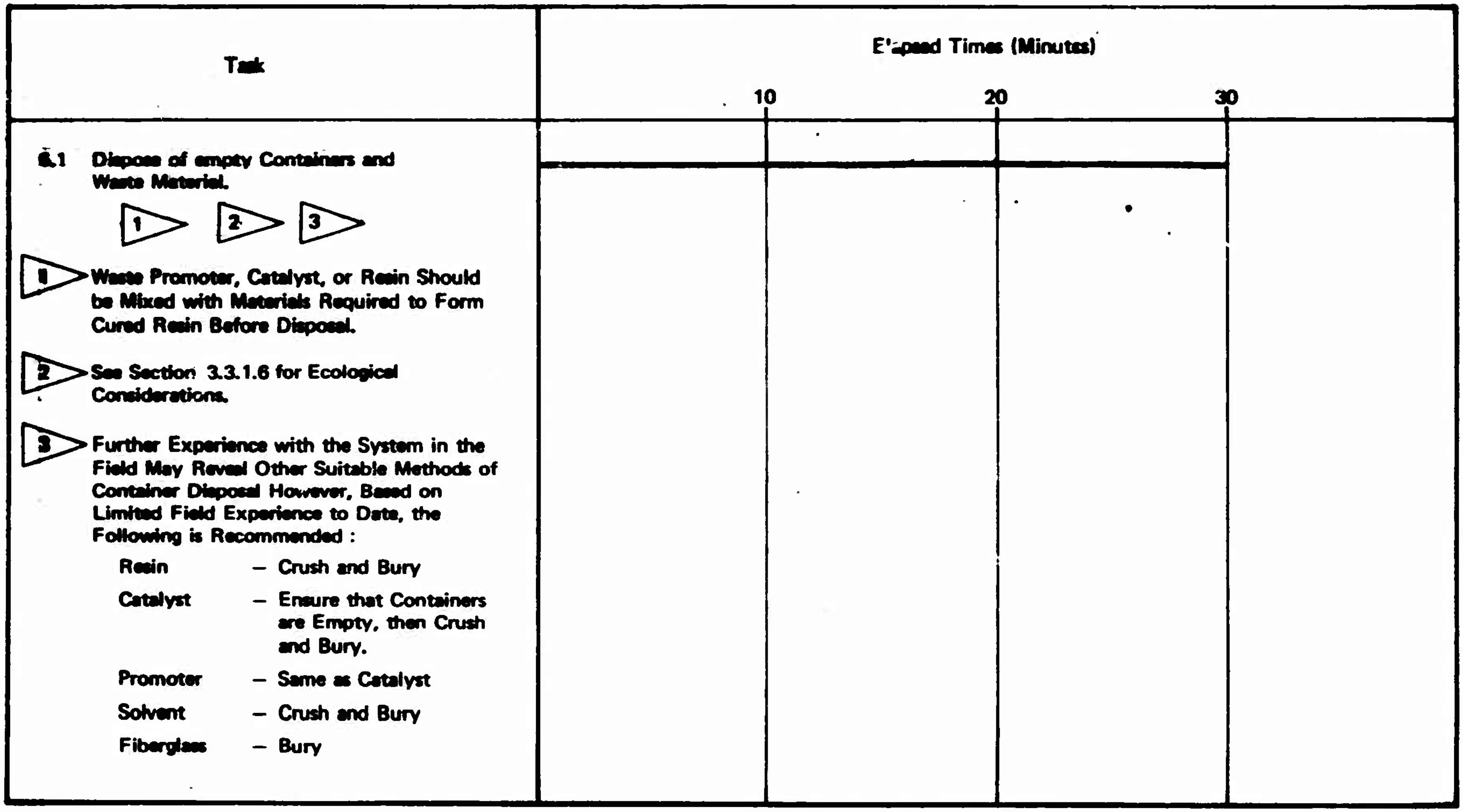


Figure 46: ***CLEANUP AREA – LOW RATE SYSTEM***

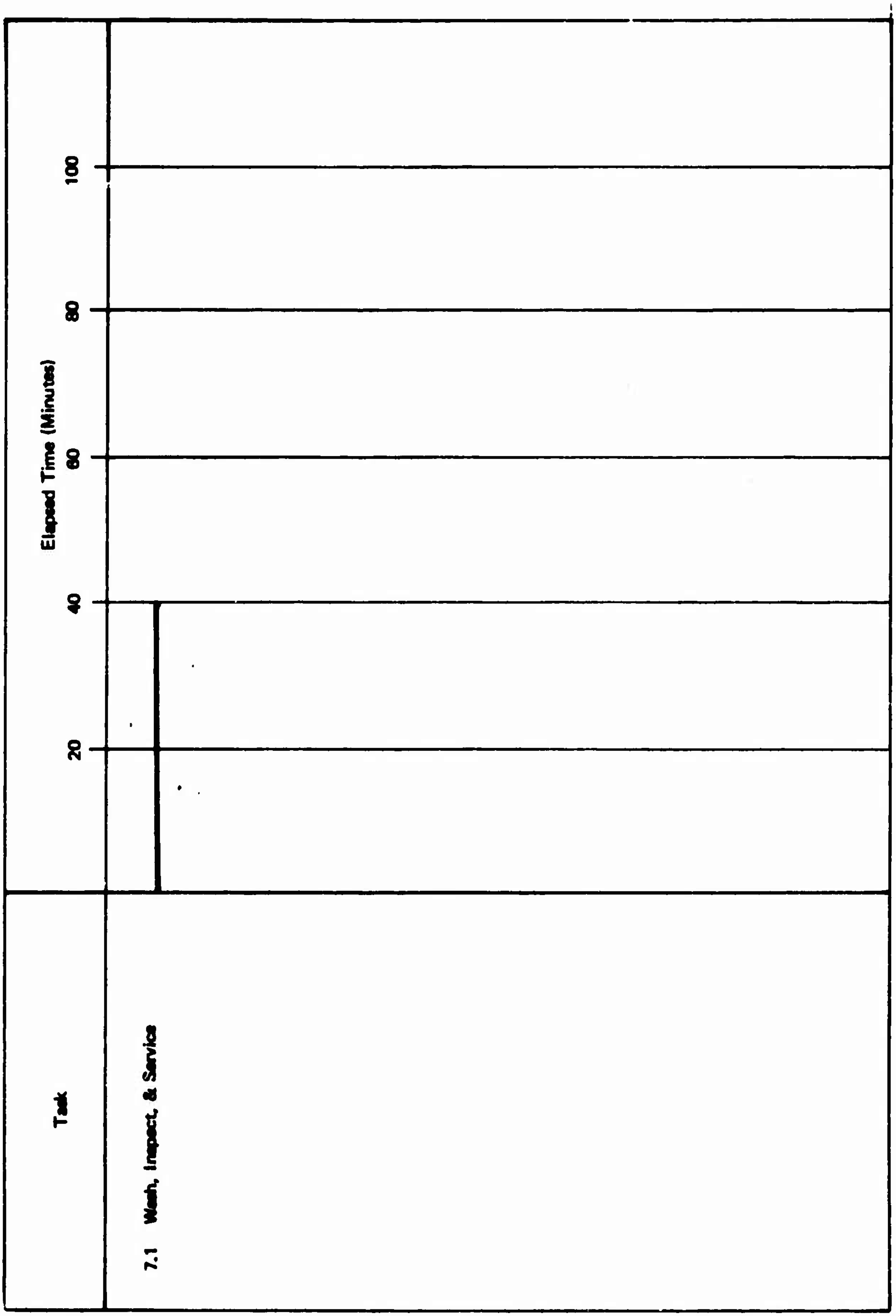


Figure 47: PREPARE EQUIPMENT FOR STORAGE – LOW RATE SYSTEM

Table 18: PERSONNEL LIST – LOW RATE SURFACING SYSTEM

Job Title	Code	Primary Job
Spraybar Operator	A	Dispenses resin
Hose Tender	B	Supports hose during spraying and paces Man "A"
Materials Handler	C	Dispense fiberglass
Roller	D	Manually rolls the wet fiberglass
Dispensing Equipment Operator	E	Operates dispensing equipment, keeps equipment supplied with liquids.

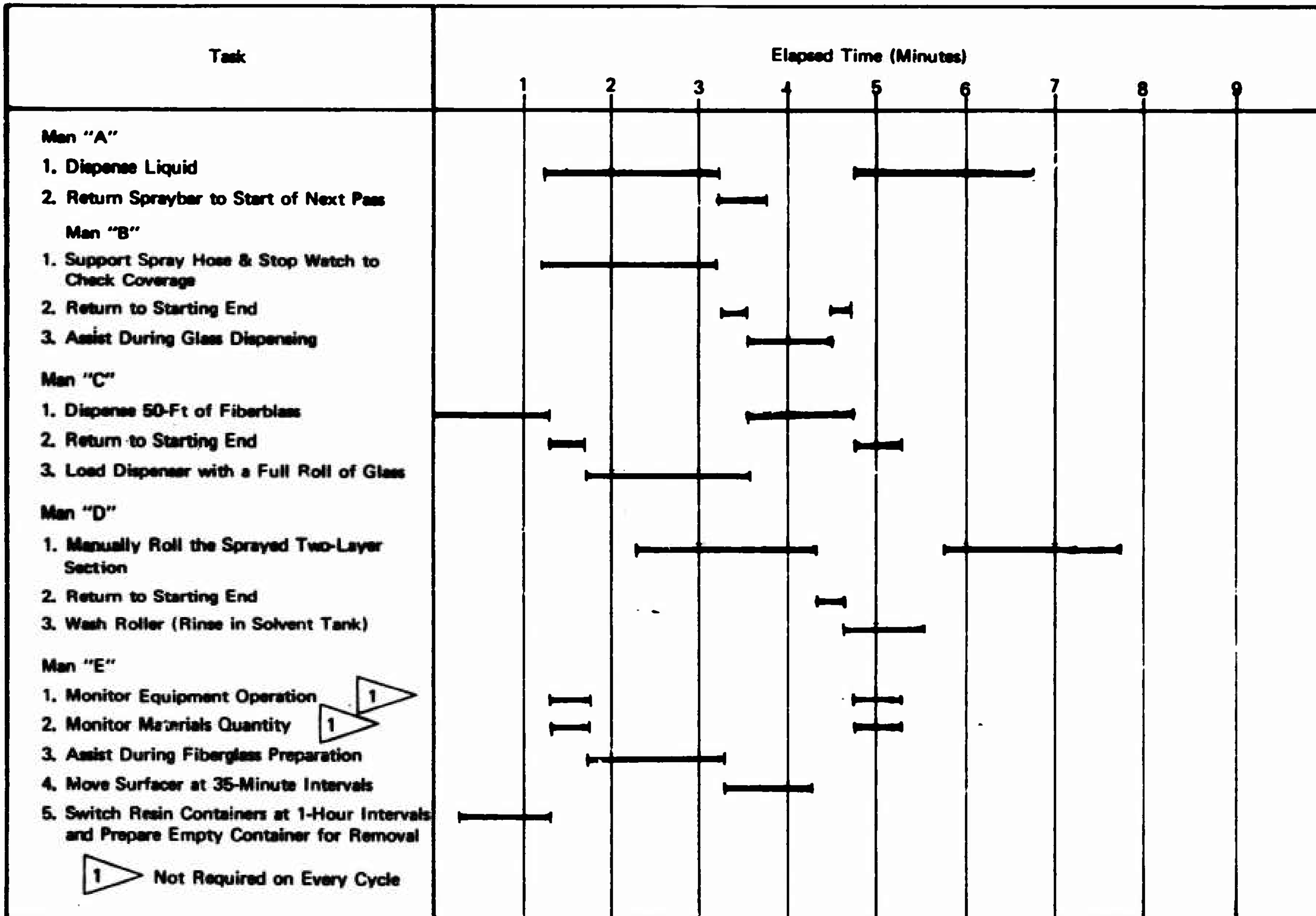


Figure 48: PERSONNEL DUTIES DURING SURFACING – LOW RATE SYSTEM

Table 19: EQUIPMENT LIST – LOW RATE SURFACING SYSTEM

Item	Qty	Function
Liquid Dispensing Unit	1	Deliver resin to matting
Glass Dispenser	1	Lay out glass matting
Forklift, Rough Terrain, 4,000 lb capacity	1	Handle materials
Hand Roller	4	Roll surfaced area
Glass Shear	1	Cut glass matting
Wash Tank	1	Clean hand rollers
Spare Fiberglass Spindles	2	Prepare fiberglass for dispensing.
Solvent Pump or Drum Spigot	1	Dispense solvent for cleaning rollers and miscellaneous equipment
Paint Brushes, Assorted Sizes	6	Cleanup
Bucket, Plastic 10 qt.	4	Cleanup
Rags	4	Cleanup
Thermometer	1	Measure air or soil temperature
Drum Handling Sling 55 Gallon	1	
Drum Handling Sling 30 Gallon	1	
Stakes	6	Position marker
Twine	1,000′	Initial guide line
Stop Watch	1	Check gel time
Steel Tape 100′	1	
Bung Wrench	1	
Eye Wash, Portable	1	
Water Jug	1	Drinking and emergency wash
Waste Cans	As Req'd	
Mechanic's Tool Set	1	Equipment setup and maintenance
Shovels	2	
Brooms	2	Cleaning joint areas
Hammer – 2 Lb.	1	Drive Stakes
Oiler		Equipment lubrication
Grease Gun		Equipment lubrication
Squeegee, Rubber	2	Spreading resin & working out wrinkles
Support Materials 1. Gasoline 2. Motor Oil 3. Metering Pump Oil (Gear Lube as required for existing temperature) 4. Grease, general purpose		

3.3.2.3.2 Operational Analysis (Cont)

The surfacing operation is conducted in the sequence shown in Figure 43. In order to achieve the required rate of 2,000 sq ft/hr, the average time allotted per 50 ft x 6.5 ft pass is 4-1/2 minutes. However, with allowances for down-time to move the equipment and load resin containers, all this time is not available resulting in a requirement to apply the strips at a frequency of about 3-3/4 minutes. The method of accomplishing this is detailed in Figure 48. During surfacing, all activities proceed in the same direction to avoid confusion. This also allows the rolling to be performed after spraying but before the next fiberglass strip is emplaced and avoids the requirement to reach across a full 6-1/2 ft wide strip with the roller. In order to enable the dispensing equipment operator to perform such tasks as assisting during fiberglass preparation and dispensing, and advancing the equipment trailer without stopping the surfacing operation, the following feature will be incorporated. Provide control over the pump drive by the spraybar operator such that once the equipment is set up, on-off capability does not require another attendant. This might be accomplished using an electric clutch controlled through a switch at the spraybar or a pressure switch upstream of the spraybar hose.

Equipment cleanup following surfacing involves essentially flushing the fluid systems, cleaning exterior surfaces and securing all loose equipment. Area cleanup is assumed to consist of transporting waste materials and debris to a disposal area.

Using the foregoing as a baseline the following variations will be considered:

(a) Smaller areas.

(b) Soft and irregular terrain.

(c) Inclement weather.

(d) Varying material package size.

o Smaller Areas

Smaller rectangular areas on level firm terrain should not affect the operation of the equipment except that for smaller areas the percentage of time expended for equipment preparation and cleanup increases, thus equipment and manpower utilization degrades. Very small or irregularly shaped areas that require a great amount of cutting and fitting of the fiberglass will obviously reduce the hourly output. In these cases the best method might be to lay out and anchor sufficient fiberglass for several minutes of spray time before dispensing any liquid. This would require nails, lengths of soft wire, or other means of anchoring the fiberglass during windy weather or on steep slopes.

3.3.2.3.2 Operational Analysis (Cont)

- <u>Soft and Irregular or Sloping Terrain</u>

Prefabrication of surfacing for revetment erosion protection, ditch or basin lining, area erosion protection, bunker construction and similar applications will require different procedures than when operating on firm level ground. Prepositioning and anchoring the fiberglass may be required. More than one light spraying pass may be required to achieve a satisfactory surface on slopes. Also fiberglass lighter than the .4 lb/sq ft baseline may be used.

For these cases the resin output should be reduced from that required to support a 2,000 sq ft per hour application rate on level terrain. Experience during testing by the USMC indicates that the maximum operator coverage rate capability on irregular surfaces is in the vicinity of 100 sq ft per minute.

For a 1 lb/sq ft surface at 60:40 resin to fiberglass ratio this would amount to 60 lbs per minute of resin. To cover the possibility of surfacing lighter than 1 lb/sq ft, a further reduction to approximately 40 lbs per minute of resin should be possible.

Operations on soil of low strength will present problems. Moving the equipment into position and loading materials will be more difficult and time consuming. The capability to add lengths of hose to extend the reach of the equipment beyond what is normally needed could be useful where terrain difficulties are encountered, and additions up to 100 ft should be considered. For maximum flexibility in situations where site access or terrain characteristics might prevent surfacing without extensive site preparation, the liquid dispensing system should be detachable from the trailer chassis and capable of operating on the ground or on another vehicle. This would allow the equipment and materials to be moved with a rough terrain forklift, helicopter sling or other available means.

- <u>Inclement Weather</u>

High and low ambient temperatures will have essentially the same effect on the low-rate system as on the high-rate system. During hot weather care is required to prevent too rapid gelation of the applied resin and to keep the catalyst temperatures below 100^{o}F. Winterization for cold weather operation should include changing the oil in crank cases, gear boxes and metering pump. At material temperatures appreciably lower than the planned for 40^{o}F, degradation of the fluid system performance can be expected.

The surfacing can be applied during light to moderate rains but again, surfacing during a heavy rain should generally be avoided. When single layer surfacing is being applied the fiberglass rolls should be left covered until they are used and should then be unrolled immediately ahead of the resin spray to avoid exposing large areas before spraying with resin. When two layer surfacing must be applied during rainfall, special procedures should be employed to avoid an accumulation of water between the laminate layers. The lap arrangement recommended for the high rate system should be employed and both rolls should be unrolled together while the spray operator alternately covers small sections of the bottom and top layers. During windy weather the technique of following the fiberglass rollout with the resin spray should be used because large areas of dry fiberglass are subject to wind pickup. Anchoring pins, weights, or other means may also be used during wind if circumstances negate the first approach.

3.3.2.3.2 Operational Analysis (Cont)

o <u>Material Modules</u>

Although the low rate system could efficiently utilize smaller liquid containers than recommended for the high rate system, the advantages previously cited for a common packaging approach are believed to be of overriding significance.

Fiberglass packages should be limited to about 200 lbs maximum to permit manual emplacement. Fiberglass packages were conservatively sized to 130 lbs for the study. Although roll sizes greater than 200 lbs could probably be handled on firm level ground, heavy rolls would be difficult to emplace under less favorable conditions. The most desirable fiberglass roll width is a function of the intended use and the handling capability. For large flat areas the widest roll that can be conveniently handled is desirable to minimize the number of lap joints. For this condition the 6.5 ft wide roll appears desirable. For such applications as edging, sidewalks, small ditches, or small irregular areas, 4 ft wide rolls are easier to handle and may prove less wasteful of material.

A summary is shown below of maximum material weight required on the trailer including two resin containers and one each promoter, catalyst, and solvent containers.

MATERIAL	PACKAGING	TOTAL
Resin 2 @ 3,000 lbs ea	540 lbs	6,540 lbs
Catalyst, 55 gal. 540 lbs	70 lbs	610 lbs
Promoter, 30 gal. 240 lbs	30 lbs	270 lbs
Solvent, 55 gal. 600 lbs	70 lbs	670 lbs
		8,090 lbs

Sufficient payload capability and space is required for the above materials and the necessary dispensing equipment.

3.4 Prototype Application Equipment Development

Development of the prototype high and low rate application equipment systems was based to a large extent on knowledge and actual surfacing experience gained during the development of the Marine Corp On-Fast surfacing system. Additionally, extensive research was conducted on the equipment developed under the Air Force's Rapid-Site program. Applicable information from Rapid Site particularly as regards surfacing rolling techniques and rolling equipment, was incorporated into the design of the surfacing equipment developed.

3.4 Prototype Application Equipment Development (Cont)

Design of both the high and low rate application equipment utilized common and similar items to the greatest degree possible consistent with each unit's performance requirements. Pump drive engines, resin pumps, metering pumps, clutches, couplings and instruments and controls were selected from the same type of equipment family. Items such as latches, access opening fasteners, tiedowns, piping components, fuels and lubricants were also the same type for both units.

Subsequent to completion of preliminary design and component selection a modification to the contract was requested by NCEL and implemented. This modification required that both equipment systems be capable of pumping and spraying polyester resins with viscosities up to and including 1,600 centipoises (CPS). Accordingly, planned system design, component selection, and development testing was reviewed and revised as necessary. Changes resulting from this modification were incorporated into the program and are reflected where applicable in the following discussion.

3.4.1 DESIGN REQUIREMENTS – HIGH RATE EQUIPMENT SYSTEM

The basic requirement for the high rate equipment system was to design and fabricate an equipment system capable of applying the surfacing materials on previously prepared surfaces such that a continuous, waterproof, load bearing surface would be obtained. In addition to the above general criteria, the design of the high rate equipment system was based on the following specific requirements.

Number of operating personnel: The system shall be capable of being operated with a military crew of not more than nine (9) personnel functioning without external support other than delivery by others to the work area vicinity of the following items: Power unit fuel, lubricants, and surfacing materials necessary to apply the specified surface covering.

Surfacing characteristics: Lightweight matting may be used on areas where vehicle traffic is light; therefore, the system shall have the capability for applying the liquid materials at various flow rates and for dispensing various weights of fiberglass matting so that different weights of surfacing can be applied over various subgrades to provide a final surface coating compatible with the particular soil properties and intended usage. A multi-layer laminate is permissible to attain the specified total surfacing weights. Impervious soils may require application of smaller amounts of resin in order to achieve proper resin-to-glass ratios than sandy soil; however, the resin-to-glass ratio in the actual cover over the soil generally shall be the same for any soil type.

Application weights: The application of the surface materials shall provide a two (2) pound per square foot surface which may be applied in two (2) layers each at one (1) pound per square foot or, if feasible in one (1) layer at two (2) pounds per square foot. The application weight of two (2) pounds per square foot is nominal; the optimum weight is that at which the fiberglass is neither resin-starved nor resin-rich. By varying the fluid pumping rate, ground speed or spray coverage rate to produce the desired surface, the system shall be capable of applying a variable surface covering weight up to and including four (4) pounds per square foot with multi-layer laminates using different mat weights.

3.4.1 DESIGN REQUIREMENTS – HIGH RATE EQUIPMENT SYSTEM (CONT)

Application areas: The system shall be capable of applying the surfacing materials specified above on areas such as those required for vehicular operation and parking, material storage, building and shelter floors, helicopter pads, airfield ramp parking areas, soil erosion prevention, protection of subgrade from water infiltration, and other similar areas. The system shall be capable of operation on the following rectangular, oval, circular or irregular shaped area surfaces.

1) Level surfaces

2) Inclined surfaces at slopes up to and including 20%

3) Vertically curved surfaces (hill or mound like) with vertical radii of not less than fifty (50) feet.

Application rates: The system shall be capable of completing the two (2) pounds per square foot surfacing specified above on areas up to 1,000 feet in length at an average sustained rate of not less than 10,000 square feet per hour for not less than five (5) continuous hours. The surfacing shall continue for the specified five (5) hours without necessity for interruption of the surfacing operations for equipment adjustments, cleaning, preparation, processing, preventative or corrective maintenance, or repair.

Self-propelled: The system shall be a self-propelled integrated unit with the surfacing application equipment mounted on a self-propelled vehicle such as cargo truck modified, if necessary, to provide the speeds specified herein and to adequately support the application equipment system and provide a suitable mobile platform for the surfacing operations.

Truck: The truck furnished as part of the self-propelled application system equipment items shall conform to the design, construction, performance and quality standards of MIL-T-45338, MIL-T-45339, MIL-T-45340 or MIL-T-45341, whichever applies to the vehicle GVW class involved.

Convoy speeds: The truck shall be capable of maintaining normal military convoy speeds while fully equipped but without surfacing materials.

Ground speed: The self-propelled unit shall possess adequate ground speed range and accurate speed control which in combination with the variable fluid pumping rate capability will permit the ground surfacing completion rates of 10,000 square feet per hour of a two (2) pounds per square foot system specified herein to be attained and to permit application of the various surface coatings as specified above.

Low speed: The self-propelled unit shall possess a low speed capability of 30 feet per minute on level ground while fully loaded with surfacing materials and with engine operating at not less than 35 percent of recommended governed speed.

3.4.1 DESIGN REQUIREMENTS – HIGH RATE EQUIPMENT SYSTEM (CONT)

Mobility: The system shall retain the mobility of the carrier vehicle. Mobility or flotation improvement efforts will be limited to wheel and tire revisions or replacements.

Support and deposit of mattings: The system shall provide for utilizing fiberglass matting wound on a roll and be capable of supporting and depositing the fiberglass mat on either side of the self-propelled carrier or directly behind the carrier. In addition to the width(s) of fiberglass selected by the contractor, the system shall accommodate fiberglass in the widths of five (5) feet and eight (8) feet.

Discharge of surfacing materials: The system shall apply to the previously placed glass mat, liquid surfacing materials properly mixed, and blended through spraybars which cover the entire width of the fiberglass mat and which can be readily positioned to discharge to either side of the application equipment unit or centered on the vehicle's path and discharging to the rear of the vehicle.

External catalyzation: The system shall incorporate an external catalyzation method such that the combining of components which bring about the curing of the resin takes place outside of the hardware system.

Fluid system: The system shall include fluid component pump drive features which permit operation of any one fluid system separately or in combination with any or all others in order to simplify system checkout and calibration.

Material supply and replenishment: The system shall employ a liquid material supply and replenishment method designed to facilitate loading and handling and to reduce materials wastage.

Cleaning and flushing: The system shall have an integral cleaning and flushing system, including separate solvent storage, on the vehicle, which can circulate solvent through the entire application equipment fluid system to thoroughly clean and remove any liquid residue which might otherwise solidify within the system lines or components. On-board waste storage shall be provided.

Component completeness: The system shall be complete and all items such as suction hoses, flushing manifolds and special supply container fittings necessary to apply the surfacing and maintain the application equipment shall be included and storage provisions for these components shall be a basic part of the pumping unit.

3.4.2 HIGH RATE EQUIPMENT SYSTEM DESIGN

Based on the stated performance/design requirements, a high rate equipment system was designed and fabricated. The following discussion details those items considered critical in meeting the performance requirements. Calculations considered critical to these items are included along with the factors and considerations leading to their selection.

3.4.2.1 Configuration

The high rate equipment system consists of two major items; the dispensing equipment and the surface rolling equipment. The initial configuration selected for the high rate dispensing equipment has previously been shown in Figure 20. The final configuration is shown in Figure 49. Three principal changes are evident. One is the change in positioning of the resin container. The side by side placement rather than both being on the right hand side, was considered a distinct advantage in providing greater equipment stability, allowed direct drive connection of the resin pump, and provided much greater convenience for the on-board materials tender. Another change is the replacement of the catalyst and promoter drum type containers with on-board storage containers ('hoppers'). These containers have approximately 1-1/2 times the capacity of the catalyst and promoter drums (drum capacity of 55 gallons and 30 gallons respectively) when the truck is on a 20% slope. Provisions are made for positioning and restraining refill drums on the containers during hopper refill. Access doors are provided in the container covers for viewing liquid level. Screens (strainers) are also provided in the container covers at the point where liquid enters from the drums. Utilization of containers improves the plumbing system to the metering pump inlets, eliminates the problem of drum indexing as evidenced on the systems mockup (Ref. Section 3.4.2.2), provides easy access to the strainers, and simplifies determining liquid levels. The third principal change is the relocation of the control stand to the left rear corner of the truck. This location was chosen because it was considered that the great majority of surfacing operations would take place to the left or the rear of the truck and thus operator visibility would be greatly improved. The other major item of the high rate equipment system is the surface rolling equipment. This consists of a tractor with roller assembly and a roller wash tank. The configuration employs several of the basic features of the Rapid-Site System. One important difference is that only the rolling function is performed by the tractor and operator, rather than combining the fiberglass layout and surface rolling functions as in the Rapid-Site System.

3.4.2.2 Placement of Components

Prior to the final placement of components, a full scale mockup of the dispensing equipment platform (Figure 50) was constructed. This was considered the best practical means of achieving satisfactory placement of components in order to achieve maximum operating personnel efficiency and convenience as well as other considerations such as safety and maintainability which are discussed in later sections of this document. The mockup shown contains surfacing material containers and simulations of materials dispensing equipment and controls in the configuration prior to the final component placement as illustrated in Figure 49.

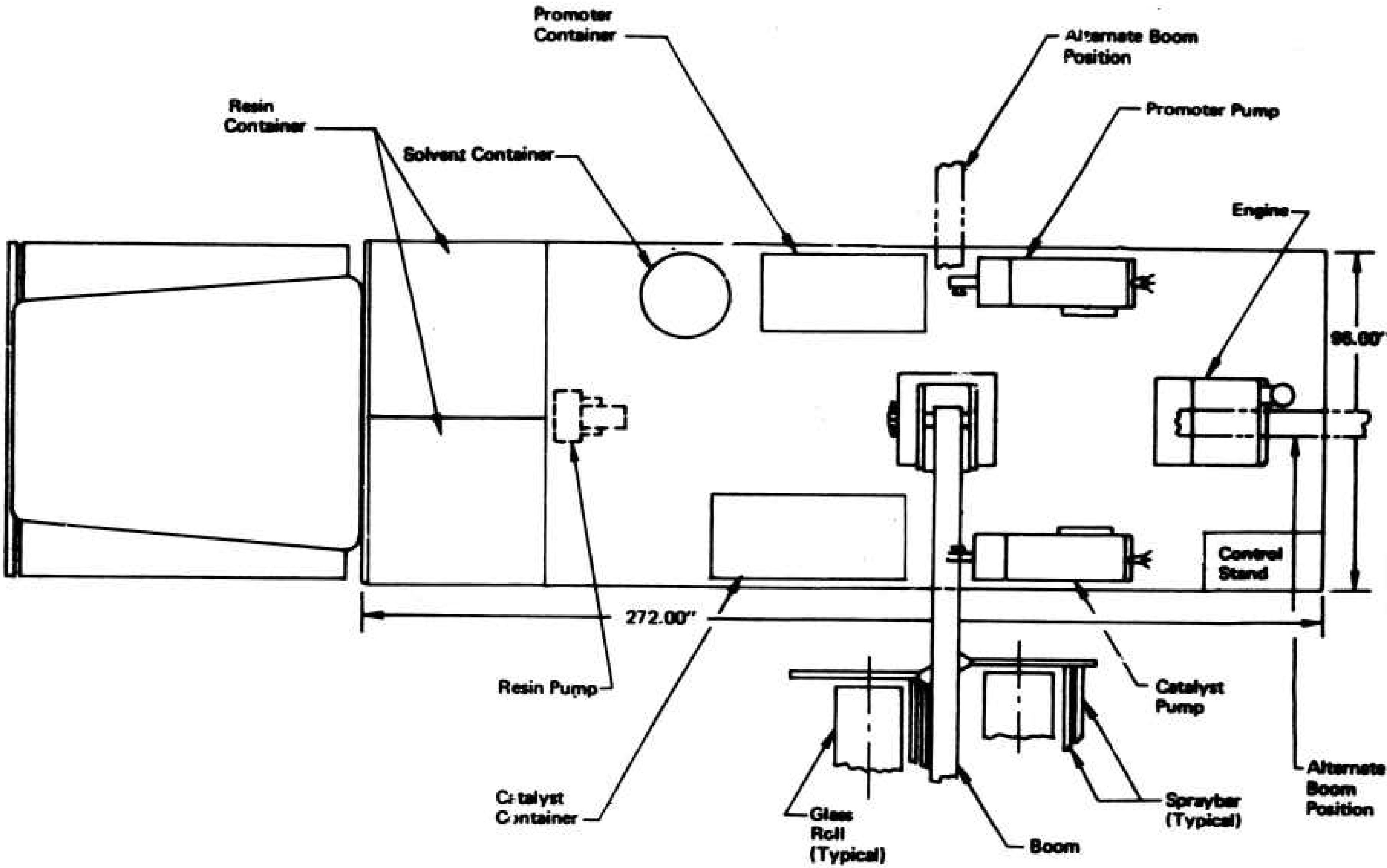


Figure 49 : HIGH RATE DISPENSING EQUIPMENT CONFIGURATION

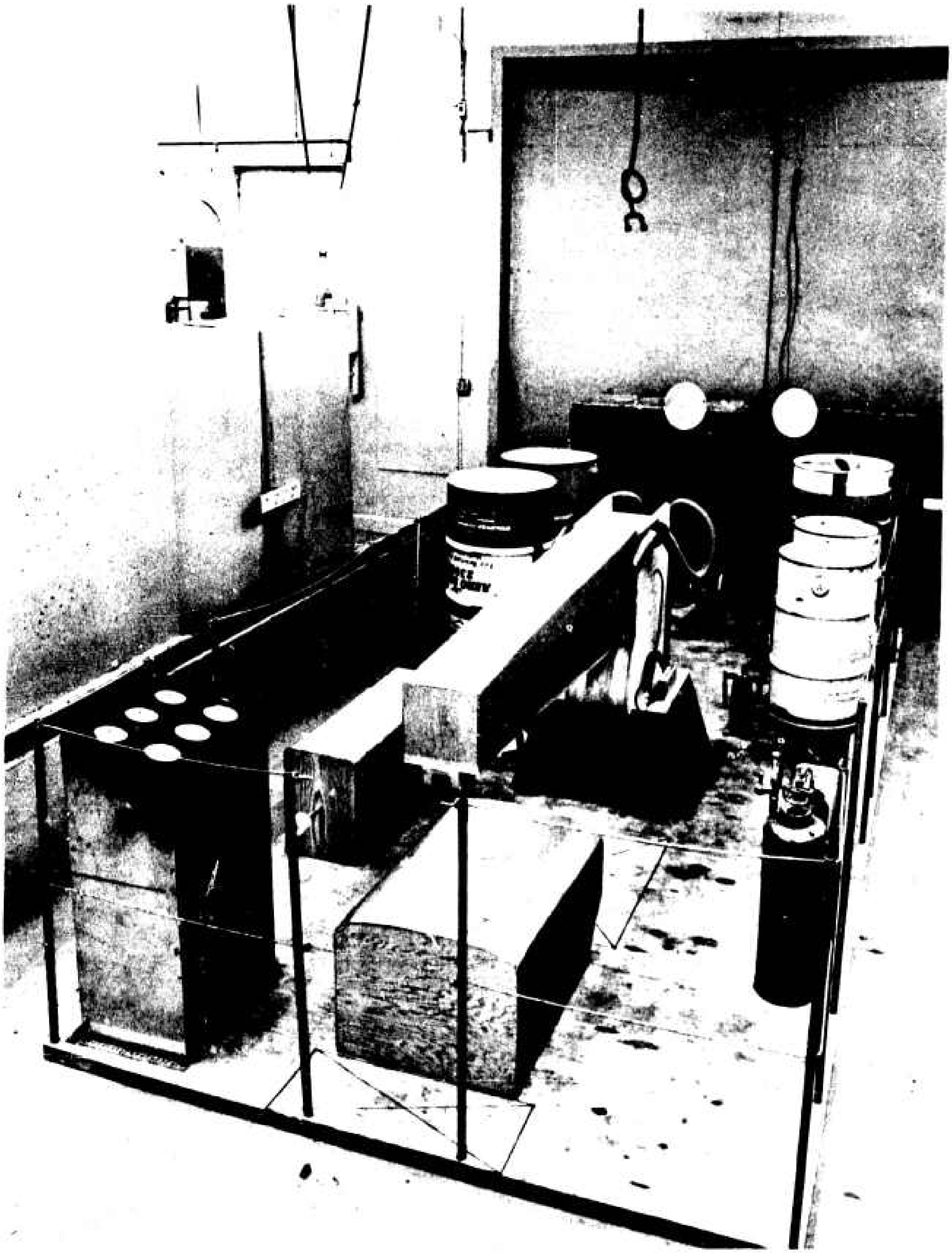


Figure 50: SPACE MOCKUP – HIGH RATE EQUIPMENT

3.4.2.3 Component Characteristics and Selection

The major components of the high rate equipment system are the carrier vehicle (truck) and its associated components (boom and turret, power plant, liquid pumps, tow tractor, roller assembly, and cleaning trough). Prior to component selection a review of commercially available components was made. Those that satisfied the design requirements were incorporated into the equipment system. Items not commercially available such as the glass rollers and roller assembly were designed based on experience with and research of previous equipment systems. Factors and considerations leading to major component selection along with calculations of critical items are discussed in the following sections.

3.4.2.3.1 Carrier Vehicle

The carrier vehicle selected for the high rate equipment system is a high gross weight, long wheel base truck per MIL-T-45341. It was obtained with a modified transmission to enable achieving speeds as low as 30 feet per minute. Table 20 lists the basic requirements and capabilities of the carrier vehicle. Overall dimensions of the carrier vehicle are shown in Figure 51. A schematic of the truck transmission modification and resulting speeds is shown in Figure 52.

3.4.2.3.2 Boom and Turret

A means of supporting the fiberglass and spraybars such that surfacing operations could be carried out from either side or rear of the carrier vehicle over surfaces of various contours was required. Therefore a hydraulically powered boom and turret was selected. Table 21 lists requirements and capabilities of the selected boom and turret. The boom has an extendable section thus allowing varying widths of fiberglass matting to be used in the surfacing system. Certification of the boom and turret is contained in the appendix.

3.4.2.3.3 Power Plant

Data for the selected power plant is presented in Table 22 and was based on a maximum system power requirement of 27 HP. Although the engine is not to military specification it has an equivalent rating comparable to MIL-E-11275. It was obtained to prevent excessive schedule delay as no comparable military specification engine was currently in production, and the production of one engine to military specification would necessitate added production and testing time of two months. Additionally a military specification engine is supplied without starter, starter switches or fuel tank and separate procurement action would be required to obtain such qualified items. It was estimated that a minimum of 3 months additional time would be required to obtain the military specification engine, starter switches, fuel tank and clutch reduction unit and assemble into the power plant package resulting in a total lead time of six months. This was considered excessive and approval was requested and obtained for the substitution of a commercial power plant.

Table 20: CARRIER VEHICLE (Sheet 1 of 3)

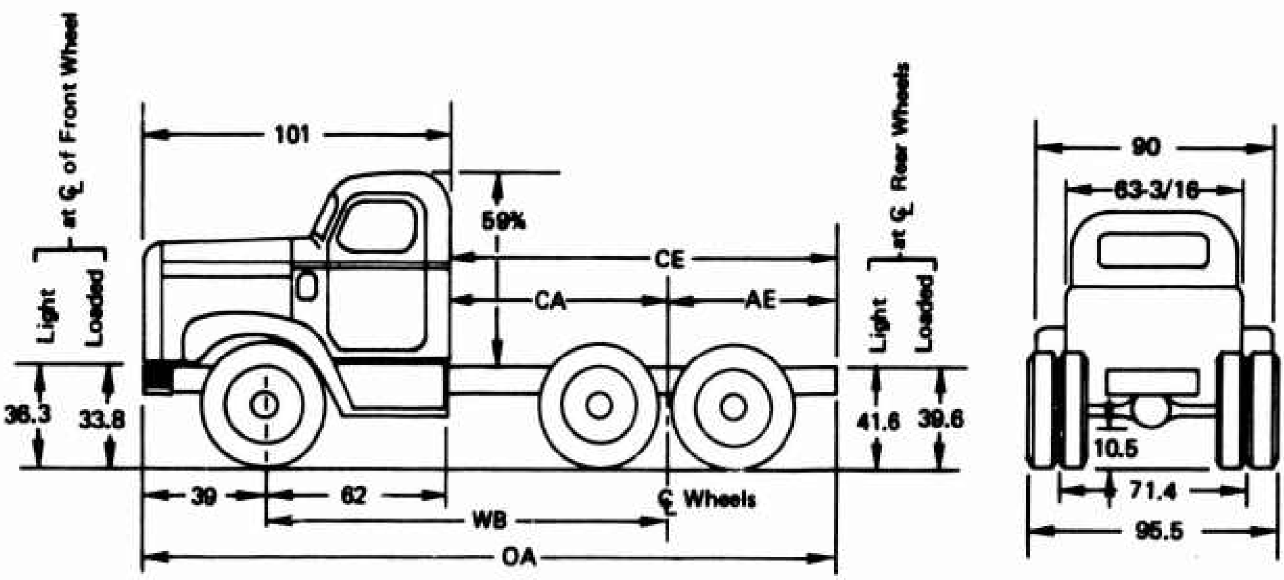
Requirements	Capabilities	Remarks
1. Truck shall be per MIL-T-45338, MIL-T-45339, MIL-T-45340, or MIL-T-45341.	1. Truck is specified to be per MIL-T-45341.	1. Supplier & Supplier Part Number. Diamond-Reo per MIL-T-45341
2. The truck shall be capable of normal military convoy speeds.	2. Truck is capable of road speeds in excess of 55 MPH.	
3. Low speed capability of 30 ft/minute at not less than 35% of recommended governed speed.	3. Extra transmission added in series to give speed control in this range.	
4. Truck should not tip over with full glass rolls at the maximum boom extension at which glass rolls will be dispensed and under the following conditions.	4. Truck will not tip as noted below:	4. Truck has mechanical suspension system lockout in order to obtain required lateral stability.
a. Tipping to left: Assumptions Made: R.H. resin tote, is empty and L.H. one is full. Both catalyst drum and hopper are full (LH side of truck) Promoter drum removed and promoter hopper ¼ full	a. With the conditions assumed, the truck has a righting moment equal to 5,359 lbs times the arm from the truck center-line to the midpoint between the rear tires.	

Table 20: CARRIER VEHICLE (Continued – Sheet 2 of 3)

Requirements	Capabilities	Remarks
8-ft fiberglass rolls used and spaced for only 6" overlap. Truck on 20% slope with left side low. Solvent barrel empty. (R.H. side of truck) b. Tipping to Right: Assumptions Made: R.H. resin tote is full and L.H. one is empty. Both promoter drum and hopper are full. (RH side of truck.) Catalyst drum removed and catalyst hopper ¼ full. (LH side of truck.) Solvent drum is full. (R.H. Side of truck.) 8-Ft. fiberglass rolls used and spaced for only 6" overlap. Truck is on 20% slope with R.H. side low.	b. With the conditions assumed, the truck has a righting moment equal to 8,388 lbs times the arm from the truck centerline to the midpoint between the rear tires.	

Table 20: CARRIER VEHICLE (Continued – Sheet 3 of 3)

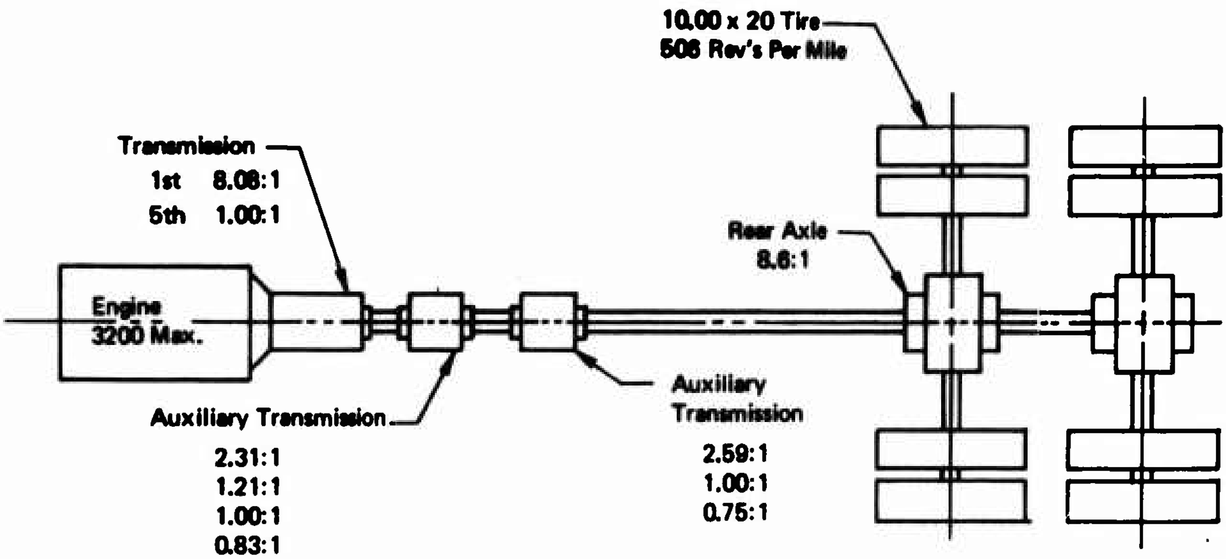
Requirements	Capabilities	Remarks
5. Truck to be capable of carrying the following loads. With glass rolls and boom behind glass truck and all containers fully loaded, the loads are distributed as follows:	5. The truck has the following: Wheel base: 224 inches. Front Axle Capacity: 12,000 lbs Rear Axle Capacity: 34,000 lbs GVW Rating: 46,000 lbs. Tires: 10.00 x 20, 12 Ply	5. The truck exceeds the following requirements specified by the manufacturer of the boom and turrett. Wheel Base: 132 inches Front axle capacity: 5,000 lbs Rear axle capacity: 13,000 lbs GVW rating: 16,000 lbs Tires: 7.50 x 20, 8-Ply



Model	WB	CA	AE	CE	OA
C-10164	224	162	96	258	359

Note: All Dimensions in Inches

Figure 51: CARRIER VEHICLE DATA



Truck Speed Calculations:

Low Speed at 35% Max. Governed RPM

(Eng RPM) x (Trans Ratio) x (1st Aux Ratio) x (2nd Aux Ratio) x (Rear Axle Ratio) x (Miles Per Rev) x (Ft Per Mile)

$$3200 \times \frac{35}{100} \times \frac{1}{8.08} \times \frac{1}{2.31} \times \frac{1}{2.59} \times \frac{1}{8.6} \times \frac{1}{506} \times 5280 = 28.1 \ \frac{\text{Ft}}{\text{Min}}$$

High Speed

$$3200 \times \frac{1}{1} \times \frac{1}{1} \times \frac{1}{0.75} \times \frac{1}{8.6} \times \frac{1}{506} \times 5280 \times \frac{60}{5280} = 59 \text{ MPH}$$

Figure 52: SCHEMATIC – TRUCK TRANSMISSION

Table 21 : ***BOOM AND TURRET***

Requirements	Capabilities	Remarks
1. Support glass rolls and spray bar assembly so that glass rolls ranging in width from 5 ft to 8 ft may be applied. (105-in. to 150-in. adjustment on support beam for rolls.) (Maximum load is 2,400 lb)	1. Rated load of boom and turret is 2,600 lb at a radius of 14 ft. 66-inch extension on the boom is possible, but only 45-in. is needed.	1. End of extendable section of the boom has an adapter to give the minimum adjustment position so as to use a standard off-the-shelf boom.
2. Truck and boom dimensions must be within the envelope that will enter a C-130 aircraft when the equipment is secured for transportation.	2. Base structure Can be cut down in order to secure the required height.	2. Cutoff and rework of the base presented no unusual problems.
3. Boom must rotate so as to position glass rolls and spraybars to left, right, or behind the truck.	3. Boom and turret are capable of 360^{0} rotation, while only 180^{0} is needed.	3. Boom rotation and elevation are hydraulically powered.
4. Boom must raise and lower in order to follow ground contours on a 50-ft radius and 20% slope.	4. Standard boom will lower 20^{0} below horizontal or raise 75^{0} above.	4. Boom controls were mounted on the control stand to provide maximum operator convenience.
		5. Supplier & Supplier Part Number: A. B. Chance, Pitman Division PC-55 Boom and Turret (Modified)

Table 22: POWER PLANT

Requirements	Capabilities	Remarks
1. Power units for operating the pumping equipment shall include electric starting systems and shall have a continuous brake horsepower rating of not less than the pumping units maximum input power requirements. Horsepower requirements are as follows: Resin Pump: 14.0 HP Catalyst Pump: 1.5 HP Promoter Pump: 1.0 HP Total Inputs of These Pumps 16.5 HP Assuming 75% Drive Efficiency: Total Engine HP on Above Pumps = 22.0	1. An electric starter is furnished with the power unit. Power output is 28 continuous horsepower at 2,150 rpm. (This is 80% of peak output as recommended for continuous operation.	Supplier & Supplier Part Number: Wisconsin Motor Corporation Model VG4D with clutch-reduction unit (2.5:1), electric starter, 30 amp alternator and variable speed governor with speed regulating control.
Electric Power for Lights: 0.5 HP Hydraulic Pump for Boom (Intermittent Only) Power Required at Maximum Rate of Change = 4.5 HP This is a maximum of 27.0 HP with a continuous load of 22.5 HP	A 30-amp alternator is provided.	
2. Clutch-reduction assembly required to match gear train requirements for pump drive.	2. A clutch-reduction assembly was provided with reduction of 2.5 to 1 as part of power unit.	
3. All engines shall conform to MIL-E-11275, MIL-E-11276, or MIL-E-62014; however should excessive schedule delay result from this requirement, then with approval of Officer in Charge of Contracts, a commercial engine of equivalent rating may be substituted.	3. Power plant engine has equivalent rating of comparable MIL-E-11275 engine.	

3.4.2.3.4 Liquid Pumps

As previously discussed in Section 3.4.1 the high rate surfacing system was required to have the capability to apply 2 lb per sq ft surfacing at a rate of 10,000 square feet per hour. A vehicle travel speed of 100 feet per minute was determined during the operational usage study as that necessary to support the required surfacing rate while dispensing 6.5 feet wide fiberglass. Also, since the system is required to dispense fiberglass rolls as wide as 8 feet, the 100 ft/min speed was applied to twin rolls of 8 feet wide fiberglass weighing .4 lb/sq ft as a basis for calculating the maximum liquid dispensing rate. A minimum rate was selected based on maintaining consistent minimum resin pump output delivery. As an example, this minimum rate provides for dispensing a single roll of 5 feet wide, .4 lb/sq ft fiberglass at 120 ft/min.

Calculations of dispensing rates for the overall liquid system and for catalyst, promoter and resin are presented below. Assuming a deposited material comprised of 40% fiberglass and 60% liquids (by weight), the total liquid system dispensing rates are as follows:

<u>MAXIMUM:</u> $8 \text{ ft} \times \dfrac{.6 \text{ lb liquid}}{\text{sq ft}} \times 100 \dfrac{\text{ft}}{\text{min}} \times 2 \text{ rolls} = 960 \dfrac{\text{lbs}}{\text{min}}$ (total liquid)

<u>MINIMUM:</u> $5 \text{ ft} \times \dfrac{.6 \text{ lb liquid}}{\text{sq ft}} \times 120 \dfrac{\text{ft}}{\text{min}} = 360 \dfrac{\text{lb}}{\text{min}}$ (total liquid)

Catalyst Pump: The surfacing materials were required to cure at temperatures from +40°F to +95°F at 100% relative humidity within 1 hour. To provide an acceptable gel time of approximately 10 to 30 minutes, the active catalyst flow rate must be variable from approximately .25 parts per 100 parts of resin by weight (PHR) to 1.5 PHR. The catalyst is 40% active; therefore, the actual liquid flow rates are .625 PHR to 3.75 PHR. Maximum catalyst required occurs with a minimum amount of promoter entered into the liquid composition and minimum catalyst required occurs with a maximum amount of promoter entered into the liquid composition. Therefore, the required catalyst dispensing rates are:

<u>MAXIMUM:</u> $960 \dfrac{\text{lbs liquid}}{\text{min}} \times \dfrac{3.75 \text{ lbs catalyst}}{104.0 \text{ lb liquid*}} = 34.6 \dfrac{\text{lbs catalyst}}{\text{min}}$

<u>MINIMUM:</u> $360 \dfrac{\text{lbs liquid}}{\text{min}} \times \dfrac{.625 \text{ lbs catalyst}}{102.125 \text{ lbs liquid**}} = 2.20 \dfrac{\text{lbs catalyst}}{\text{min}}$

(*liquid composition is 100 parts resin + 3.75 parts catalyst + 0.25 parts promoter)

(**liquid composition is 100 parts resin + 0.625 parts catalyst + 1.5 parts promoter)

Based on the calculated catalyst dispensing rates and the requirement for variable flow rate a metering type pump was selected for this application. Table 23 lists the requirements and capabilities of the selected pump.

Table 23: CATALYST PUMP

Requirements	Capabilities	Remarks
1. Deliver 34.6 pounds per minute of Noury Corp. S0046 (Green) 40% active catalyst-emulsion and deliver any desired lesser amount down to 5.8 pounds per minute without changing the pump speed. Also be capable of delivering catalyst at rate proportionately lower when operating at slower speeds to match the resin output. This slower speed is approximately 38% of the maximum. Minimum catalyst delivery rate is 2.2 pounds per minute. Maximum expected catalyst viscosity at $40^{\circ}F$ is 7000 centipoises.	1. The pump will deliver 616 gal. per hour (approx. 100 lbs/min) at 92 strokes per minute. The output is adjustable downward to zero. The pump output is proportional to speed from 46 to 140 strokes per minute. This type of pump is capable of handling high viscosity fluids.	1. Supplier & Supplier part number: Milton Roy Company Model C Simplex Packed Plunger Pump No. MR1 (less drive motor) with 3" stroke and 3½" diameter plunger.
2. Deliver catalyst at pressures required to inject into the resin at maximum resin system pressure (177 psi).	2. The pump is capable of delivering fluid at pressures to 230 psi.	2. Recommended motor size for required flow conditions is 1½ H.P. The pump as used in the high rate system is driven from the power plant through a mechanical drive system with 1½ H.P. allocated for pump drive requirements.

3.4.2.3.4 Liquid Pumps (Cont)

Promoter Pump: Similarly to the catalyst pump, the promoter pump selected must provide variable flow control and be capable of supplying sufficient promoter (.25 PHR to 1.5 PHR) to effect surfacing materials cure under the stated temperature and humidity conditions. The maximum and minimum promoter required occurs when minimum and maximum amounts respectively of catalyst are entered into the liquid composition. Therefore the required promoter dispensing rates are:

MAXIMUM: $$960 \frac{\text{lbs liquid}}{\text{min}} \times \frac{1.5 \text{ lbs promoter}}{102.125 \text{ lbs liquid*}} = 14.1 \frac{\text{lbs promoter}}{\text{min}}$$

MINIMUM: $$360 \frac{\text{lbs liquid}}{\text{min}} \times \frac{.25 \text{ lbs promoter}}{104.0 \text{ lbs liquid**}} = .865 \frac{\text{lbs promoter}}{\text{min}}$$

(*liquid composition is 100 parts resin + 0.625 parts catalyst +1.5 parts promoter)

(**liquid composition is 100 parts resin + 3.75 parts catalyst + 0.25 parts promoter)

As was the case with the catalyst pump a metering type pump was selected for promoter dispensing and Table 24 lists the requirements and capabilities of the pump selected.

Resin Pump: The maximum resin amount required results when the least amounts of catalyst and promoter required to effect cure are entered into the liquid composition. Minimum resin amount required results when the greatest amounts of catalyst and promoter required to effect cure are entered into the liquid composition. Therefore, based on maximum and minimum catalyst and promoter required, resin dispensing rates are:

MAXIMUM: $$960 \frac{\text{lbs liquid}}{\text{min}} \times \frac{100 \text{ lbs resin}}{100.875 \text{ lbs liquid*}} = 951.7 \frac{\text{lbs resin}}{\text{min}}$$

MINIMUM: $$360 \frac{\text{lbs liquid}}{\text{min}} \times \frac{100 \text{ lbs resin}}{105.25 \text{ lbs liquid**}} = 342.0 \frac{\text{lbs resin}}{\text{min}}$$

(*liquid composition is 100 parts resin + 0.625 parts catalyst + 0.25 parts promoter)

(**liquid composition is 100 parts resin + 3.75 parts catalyst + 1.5 parts promoter)

The positive displacement pump described in Table 25 was selected based on the above resin dispensing requirements and satisfactory performance of similar type pumps used in the On-Fast system.

Table 24 : TABLE PROMOTER PUMP

Requirements	Capabilities	Remarks
1. Deliver dimethyl aniline at any desired rate from 14.1 lbs per minute to 2.3 pounds per minute without changing the pump speed. Also be capable of delivering promoter at rates proportionately lower when operating at slower speeds to match the resin output. This slower speed is approximately 36% of the rated maximum. Minimum promotor delivery rate is 0.8 pounds per minute. Promoter viscosity ranges between 2 centipoises at 40°F and 1 centipoises at 95°F.	1. The pump will deliver 118 GPH (Approx 15.7 pounds/min.) at 140 strokes per minute. The pump output is adjustable downward to zero and is proportional to speed from 46 to 140 strokes per minute.	1. Supplier & Supplier part number: Milton Roy Company Model B Simplex Packed Plunger Pump No. MR1 (less drive motor) with 1½" stroke and 1¾" bore.
2. Deliver promoter at pressures required to inject into the resin at maximum resin system pressure (177 psi).	2. The pump is capable of delivering fluid at 360 psi.	2. Recommended motor size for required flow conditions is 1 H.P. The pump as used in the high rate system is driven from the power plant through a mechanical drive system with 1 H.P. allocated for pump drive requirements.

Table 25 : RESIN PUMP

Requirements	Capabilities	Remarks
1. Deliver 952 pounds per minute maximum to 342 pounds per minute minimum by changing the pump speed. Resin viscosity range to be accommodated is 80 to 1000 centipoises (CPS).	1. The pump is rated at up to 140 GPM (approx. 1290 pounds per minute) for fluids having a viscosity up to 7500 SSU (1830 CPS). Flow is approximately proportional to RPM.	1. Supplier & Supplier Part Number – Viking Pump Division of Houdaille Industries, Inc. Model Q 124
2. Deliver resin at pressures as high as 200 psi.	2. The pump is rated for 200 psi when pumping liquid having a viscosity greater than 100 SSU (23 CPS).	2. This type of pump has been used in the ON-FAST system and has exhibited consistent, reliable service.

3.4.2.3.5 Tow Tractor

Selection of a vehicle for towing the roller assembly during surfacing operations was based on the Rapid-Site system. Therefore, a review of readily available commercial tractors (Table 26) was accomplished and a standard, gasoline engine powered, commercial type tractor shown in Figure 53 equipped with an SAE Category I, 3 point hitch was selected. This type of hitch, equipped with a lifting mechanism, was required to support the 1350 pound roller assembly and aid in positioning the roller assembly during surfacing and cleaning operations. Additionally the selected tractor had a low speed capability less than 100 feet per minute. This low speed capability, matching that of the carrier vehicle when applying surfacing materials at the rate of 10,000 square feet per hour, allowed synchronization of the overall surfacing operation.

3.4.2.3.6 Roller Assembly

The roller assembly design was based to a large extent on the roller assembly previously used with the Rapid-Site System. Basically the assembly also shown in Figure 53 consists of rollers and supporting framework with adapters for attaching to the tractor lift mechanism. In its normal configuration both 5 and 6.5 foot wide fiberglass may be rolled. A longer pivot tube allowing attachment of additional roll segments is supplied to enable rolling 8 foot wide fiberglass.

Two items were considered critical in the design of the rolling equipment. One was the minimum degree of rolling pressure required such that adequate strength of the field applied surfacing would be obtained. The other was the configuration of the roller discs, considered of prime importance to ensure adequate cleaning of the rollers during field surfacing operations.

In order to define the minimum rolling effort required for field applied materials, laboratory surfacing samples were fabricated using hand rollers and applying various rolling pressures. Single pass rolling was evaluated to ascertain if satisfactory surfacing could be obtained using a single bank of rollers. The maximum number of passes with the roller was held to two as the practical maximum required for achieving the required surfacing strengths. This was also based on results obtained during the surfacing materials verification portion of program. These results indicated that application of more than two passes appeared to result in diminishing returns on strength increase. Samples, fabricated at a nominal 2 lbs per sq ft, were composed of approximately 40% fiberglass and 60% resin by weight. All resin formulations were 1.0 PHR active benzoyl peroxide (2.5 PHR catalyst emulsion) and 0.2 PHR dimethyl aniline promoter. Test specimens were obtained from the prepared samples and tested per ASTM standards for flexure, tension, and shear. Table 27 summarizes the results of this work. In general, the strength test results show increasing strength with increasing roller pressure. It is felt that this increase is a result of a higher fiberglass to resin ratio occurring as the added pressure forces an increasing amount of resin out of the laminate. No correlation was obtained in the percent deviations occurring between individual conditions of flexure, tension and shear for a given roller pressure versus one or two passes. However, the average of the percent deviations was found to be lower for the two rolling pass condition. For the single pass condition the average percent deviations ranged from 3.7% (shear) to 7.0% (tension) and for

Table 26: TRACTOR CHARACTERISTICS

Name	Model	Cost	Weight	SAE Category I 3 Point Hitch Available	Low Speed Capability	Remarks
International	154 Lo-Boy	$2,650+	1,630	No	255 Ft/Min	88 Ft/Min Low Speed Available With Optional Gearing
Kubota	L 210	$2,200	2,160	Yes	85 Ft/Min	Diesel Engine – Not Compatible With Equipment System
Ford	2000	$4,000 Total	5,230	Yes	Less Than 80 Ft/Min	
John Deere	JD 301	$4,500	4,180	Yes	106 Ft/Min	

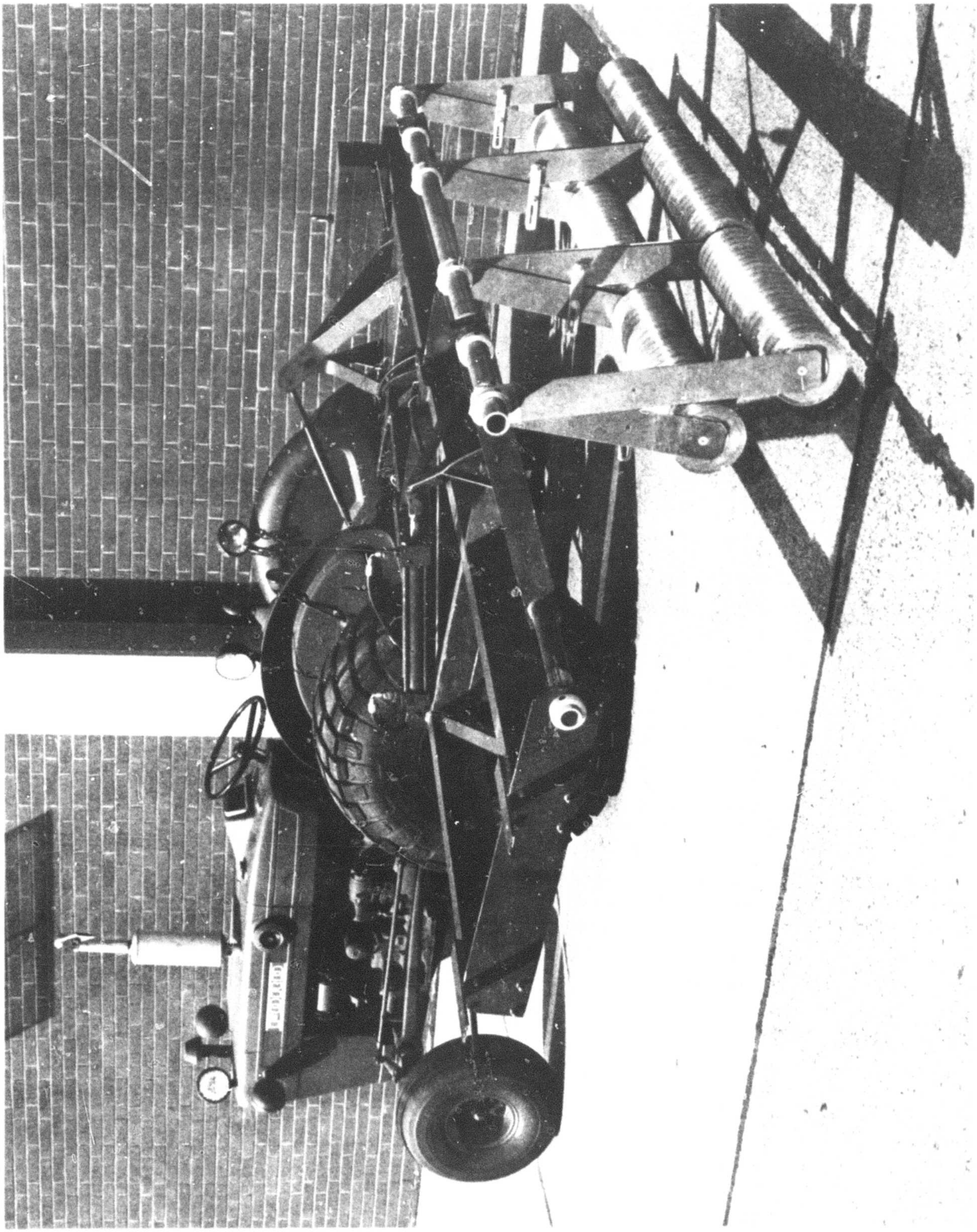


Figure 53: ROLLING EQUIPMENT

Table 27 : ROLLING PRESSURE EVALUATION SUMMARY

Rolling Pressure (Lbs per Lineal Inch of Roller)	Weight Added to Roller (Lb)	Number of Passes	Strengths (PSI)			Remarks
			Flexure	Tension	Shear	
0.144	0	1				Not Strength Tested – Large Air Pockets Between Fiberglass Layers Both 1 & 2 Passes
		2				
0.266	1-1/4	1	41,940	19,043	15,003	Incomplete Resin Penetration – Numerous Air Bubbles Evident Both 1 and 2 Pass Samples
		2	41,866	18,249	14,666	
0.388	2-1/2	1	41,367	19,910	15,048	Incomplete Resin Penetration– Air Bubbles Apparent
		2	40,454	19,843	15,090	Some Incomplete Resin Penetration– Small Amount of Resin Displaced
0.514	3-3/4	1	42,273	20,068	15,106	Same as Above
		2	42,384	19,758	14,892	Good Resin Penetration – Noticeable Amount of Resin Displaced
0.632	5	1	42,267	20,181	15,821	Same as Above
		2	42,475	20,077	15,639	Good Resin Penetration – Large Amount of Resin Displaced
1.212	10	1	43,728	20,614	15,652	Complete Resin Penetration Large Amount of Resin Displaced

Notes: 1 Specimens Made With PPG Resin 5000 SC19-143

2 Minimum Field Rolling Pressure Required 0.632 Lb per Lineal Inch Assumed
All Laboratory Strengths Exceed Required Field Strengths By a Minimum of 25%

3.4.2.3.6 Roller Assembly (Cont)

the two pass condition from 3.6% (shear) to 5.7% (flexure). Additionally, as the rolling pressure was increased, visual observations indicated that the frequency and size of air bubbles entrapped in the laminate decrease while the amount of resin displaced by the rolling action increases. This resin displacement was both ahead of the roller in a 'bow wave' manner as well as laterally. Based on the above evaluations, as well as the previous design in the Rapid-Site System, the roller assembly design provided an equivalent two pass operation, the equivalent of two passes being achieved by tandem roller banks towed by a single vehicle.

Prior to final selection of the roller disc configuration a roller segment of the Rapid-Site equipment was obtained and evaluated for both rolling and cleaning effectiveness. This evaluation was accomplished by preparing laminates directly over soil and subjecting them to two passes with the roller segment. Visual observation indicated satisfactory results both in basic laminates and in areas of overlap. Cleaning of the rollers which were of aluminum alloy, was difficult, due to the pronounced corrosion and to the pronounced rectangular cross-section of the grooves. Accordingly, the rollers for the high rate system were designed utilizing a more corrosion resistant aluminum alloy (6061-T651). The roller grooves as illustrated in Figure 54 were designed with a slight taper on the sides of the grooves and incorporated a circular rather than rectangular section at the bottom of the grooves.

3.4.2.3.7 Cleaning Trough

As in the Rapid-Site equipment system a trough was provided to allow adequate roller cleaning during and after field surfacing operations. Basically similar to the Rapid-Site equipment, the trough is of sufficient size to allow cleaning of the 8 foot wide roller segment. Roller cleaning is accomplished by positioning the rollers in the solvent filled trough and manually operating the nylon bristle cleaning brush.

3.4.2.4 Fluid Dispensing System

The fluid dispensing system for the high rate equipment system is considered a three component (resin, catalyst, and promoter) liquid system. Design was based to a large extent on the previous liquid systems developed for the On-Fast equipment. Figures 55, 56, and 57 show schematically the major elements of the individual reactive liquid systems developed during the Advanced Systems program. In addition to the above liquid systems the system also shown schematically in Figure 55 was developed to adequately clean and flush all components of the liquid system.

In the resin system, resin is drawn from either liquid container through 3 inch flexible suction hoses. During surfacing operations resin quantity remaining in these containers is monitored by the on-board materials tender. Resin flow from the containers to the pump is controlled by means of a manually operated selector valve. From the discharge side of the resin pump (mounted below deck) a 3 inch line is split into two 2-1/2 inch lines that run aft to just forward of the boom turret. These lines are routed up through the deck at this point. Resin flow continues to the individual spraybars as illustrated in Figure 58.

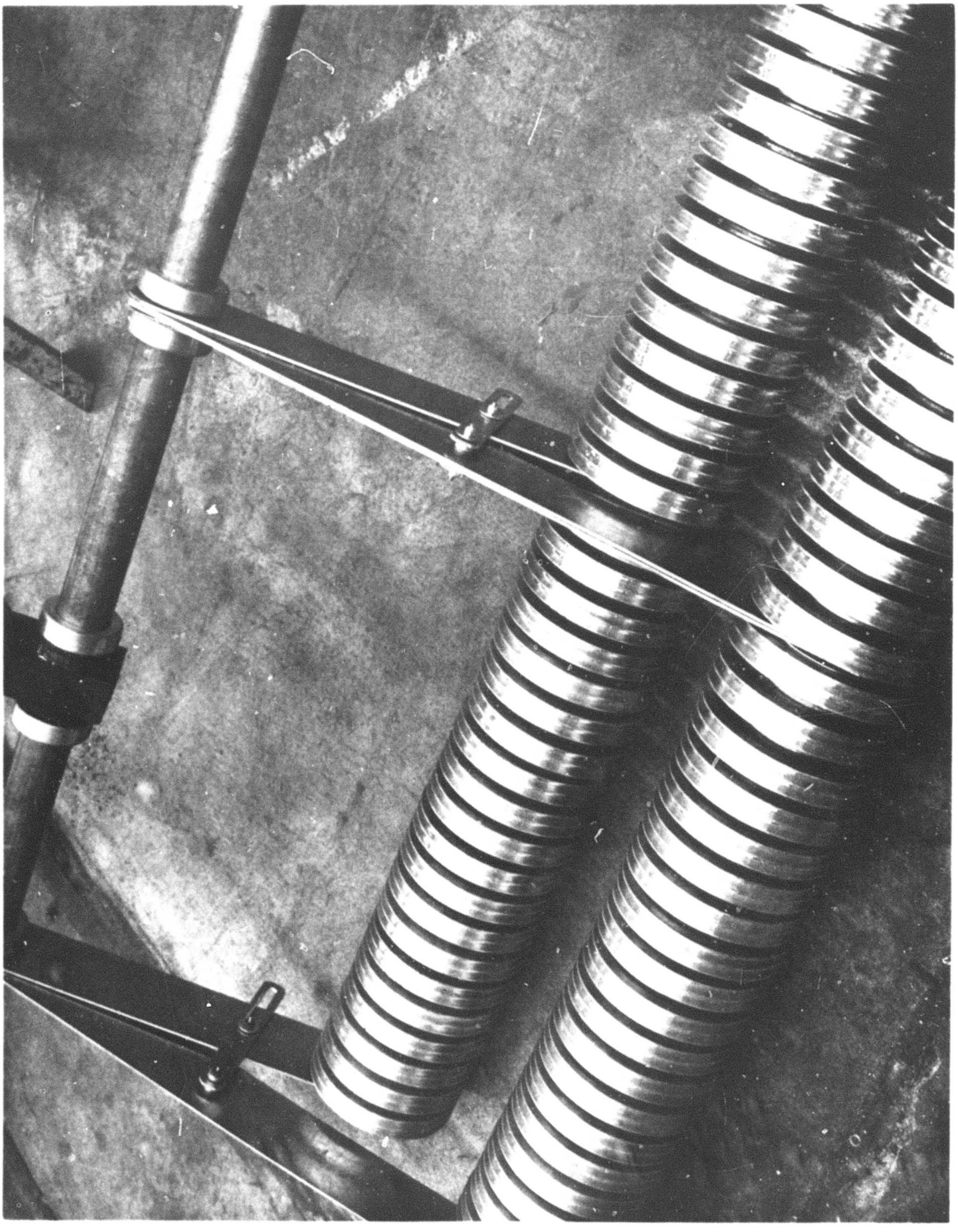


Figure 54 : ROLLER DISCS

No.	Name	Qty.	Description
1.	Resin Container	2	Plywood, Approximately 380 Gal.
2.	Connector Assembly, Resin Container	2	Part of Resin Container
3.	Piercer, Resin Container	2	
4.	Disconnect, Resin	2	With Integral Shut-off
5.	Selector Valve, Resin	1	Manually Operated 3-Way Plug Valve
6.	Temperature Gage, Resin	1	-75 to + 225 Degree F
7.	Strainer, Resin	1	14 Mesh
8.	Pump, Resin, with Relief Valve	1	Viking O-124
9.	Pressure Gage, Resin	1	0 to 300 psi
10.	Check Valve, Resin	2	
11.	Blender	2	
12.	Selector Valve, Spraybar	4	Electric motor, Remote Control Valves
13.	Spraybar		
14.	Nozzle	54	54 Max. No. (50 Used with Spray Bars for 8-Ft Glass Rolls)
15.	Injector, Promoter	2	
16.	Injector, Catalyst	2	
17.	Bleed Valve, Resin or Solvent	1	
18.	Shut-Off Valves Prewet Spray	2	
19	Solvent Drum	3	55-Gallon
20.	Adapter	2	
21.	Shut-Off Valve Solvent	1	
22.	Solvent Pump	1	Electric Driven (12-Volt)
23.	Solvent Spray Gun	1	

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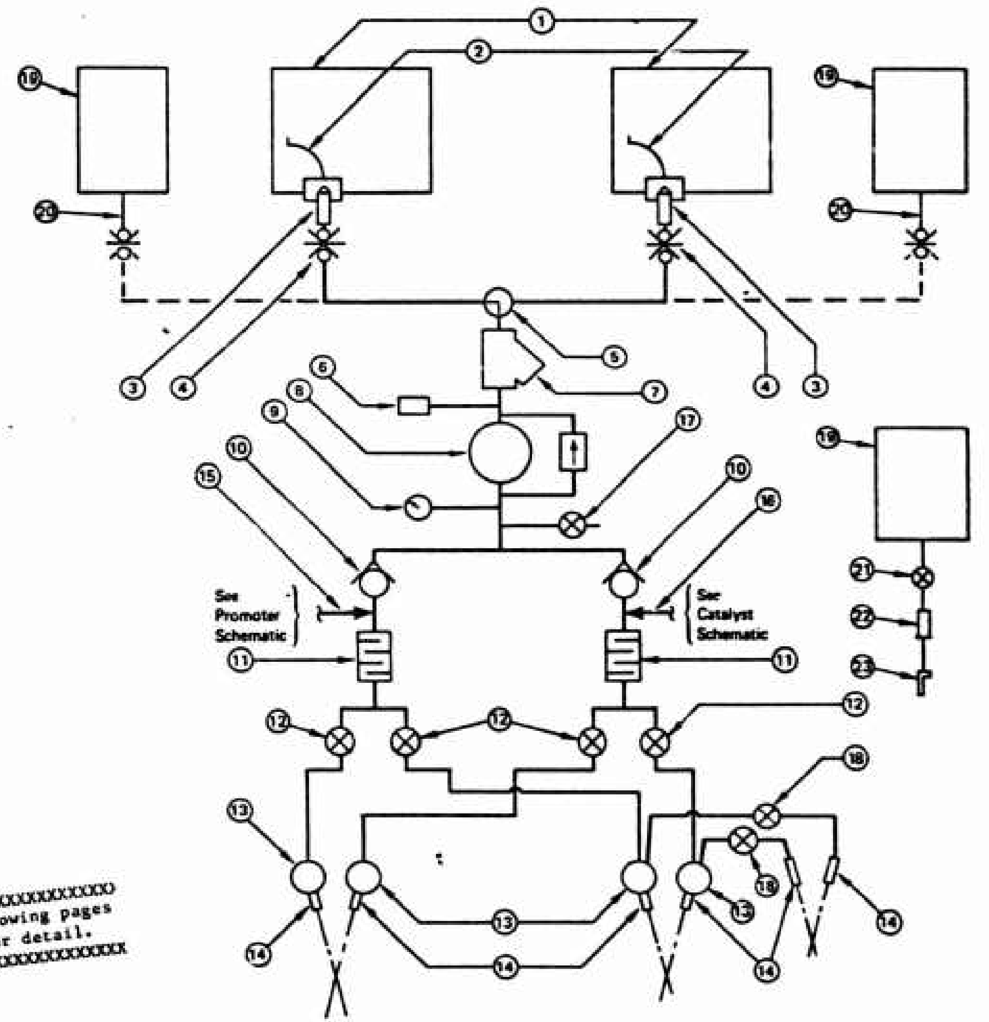
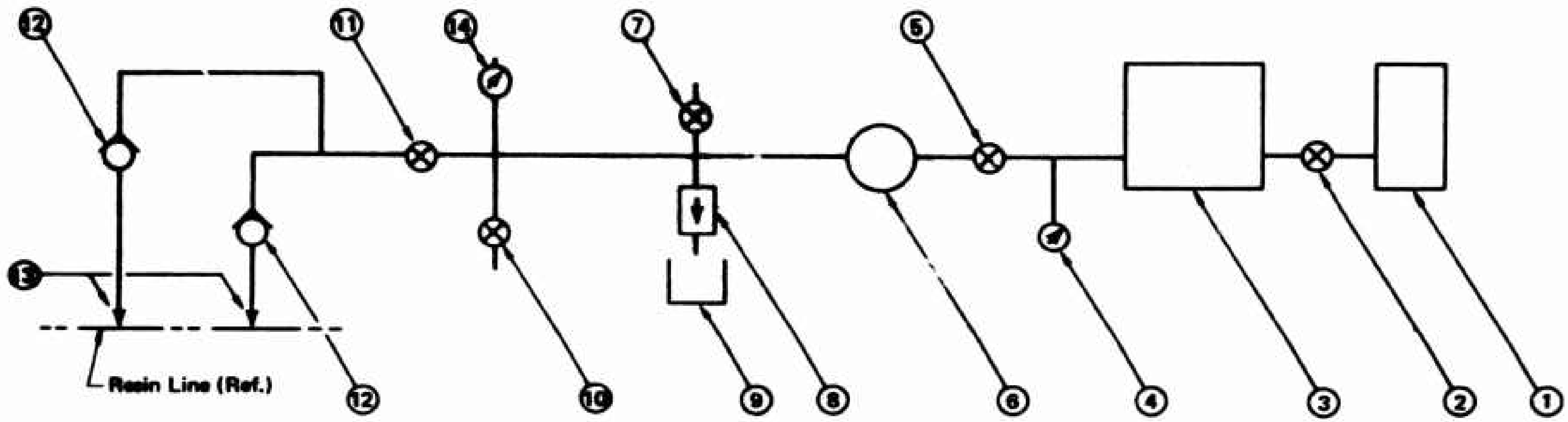
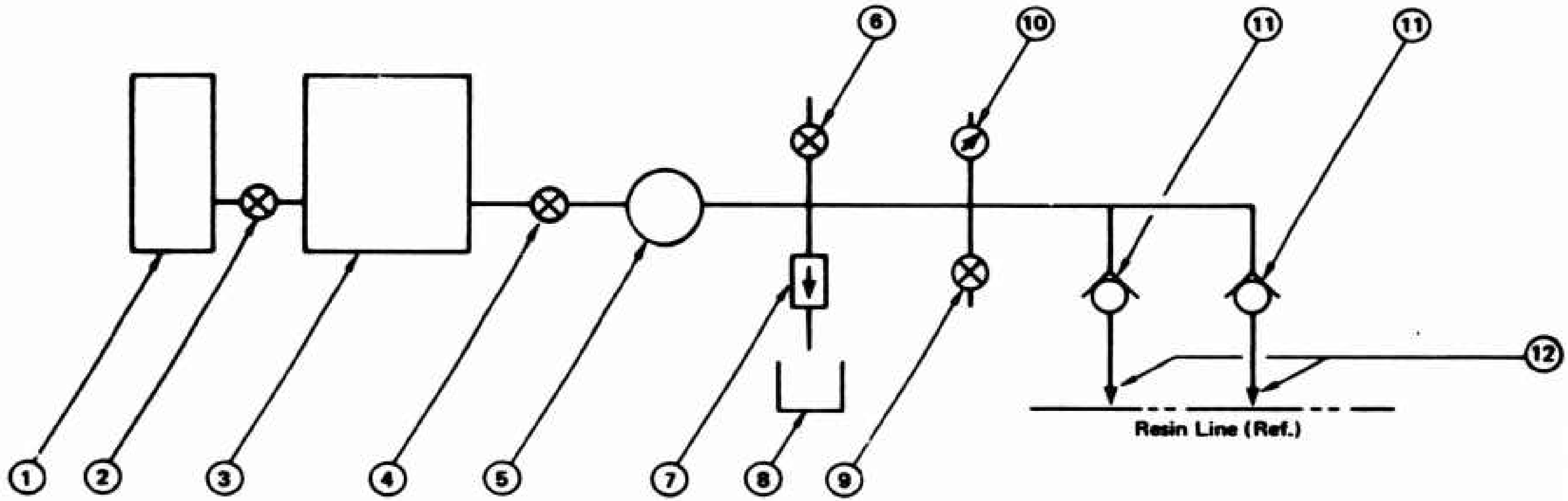


Figure 55: RESIN SYSTEM SCHEMATIC



No.	Name	Qty	Description
1	Catalyst Drum	1	55-Gallon Standard Drum
2	Catalyst Supply Valve	1	
3	Catalyst Reservoir	1	
4	Temperature Gage Catalyst	1	Remote Reading
5	Catalyst Shut-Off Valve	1	
6	Pump, Catalyst Metering	1	Milton Roy
7	Catalyst Bleed Valve	1	
8	Relief Valve, Catalyst	1	
9	Plastic Pail for Catalyst Overflow	1	
10	Catalyst Drain Valve	1	
11	Catalyst Shutoff Valve	1	
12	Check Valve	2	
13	Catalyst Injector	2	
14	Pressure Gage Transducer	1	For Remote Reading Gage

Figure 56 : *CATALYST SYSTEM SCHEMATIC*



No.	Name	Qty	Description
1	Promoter Drum	1	30-Gallon Standard Drum
2	Promoter Supply Valve	1	
3	Promoter Reservoir	1	
4	Promoter Shut-Off Valve	1	
5	Pump, Promoter Metering	1	Milton Roy
5	Promoter Drain Valve	1	
7	Relief Valve, Promoter	1	
8	Plastic Pail for Promoter Overflow	1	
9	Promoter Drain Valve	1	
10	Pressure Gage Transducer	1	for Remote Reading Gage
11	Check Valve	2	
12	Promoter Injector	2	

Figure 57 : PROMOTER SYSTEM SCHEMATIC

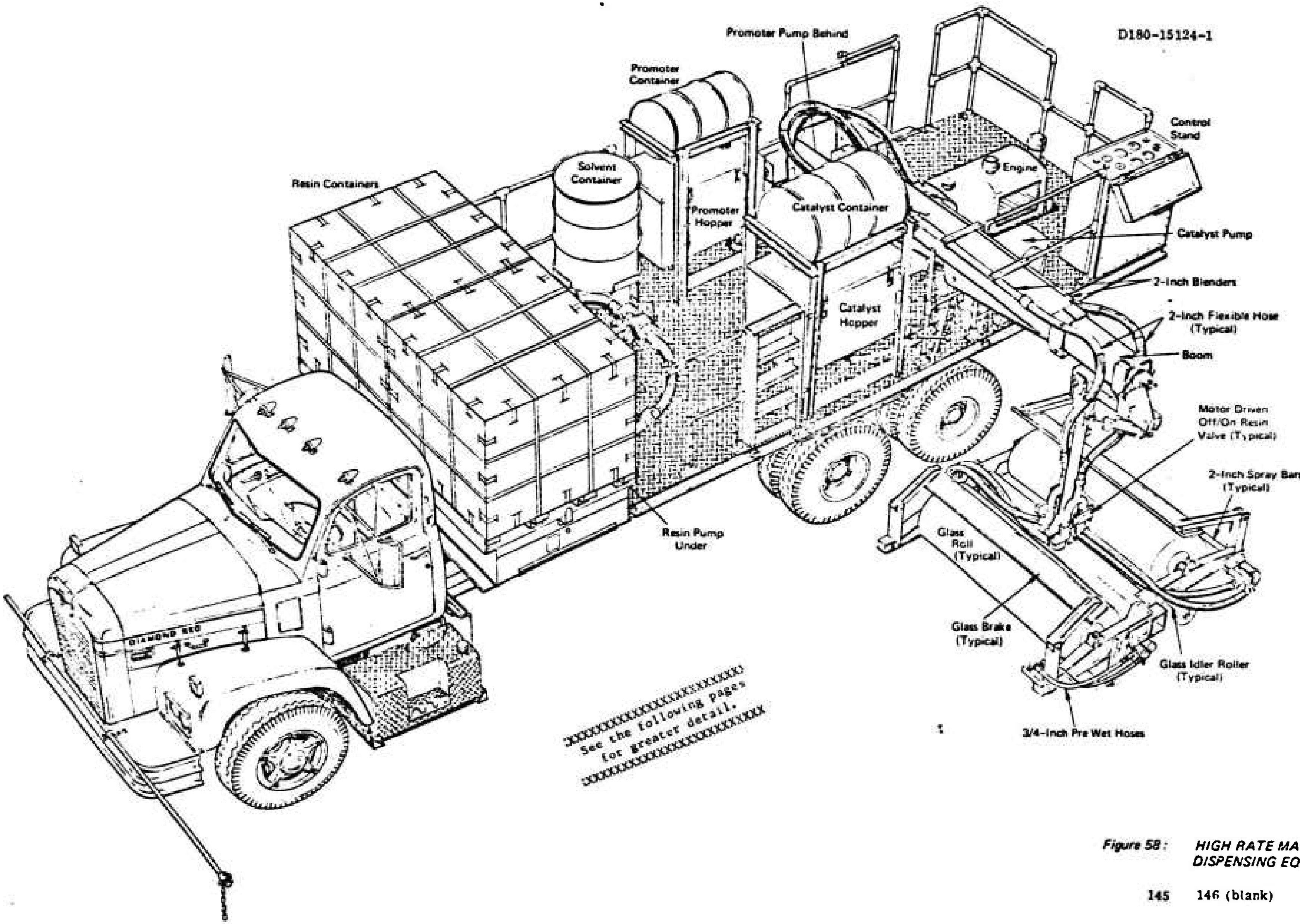


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Figure 58: ***HIGH RATE MATERIALS DISPENSING EQUIPMENT***

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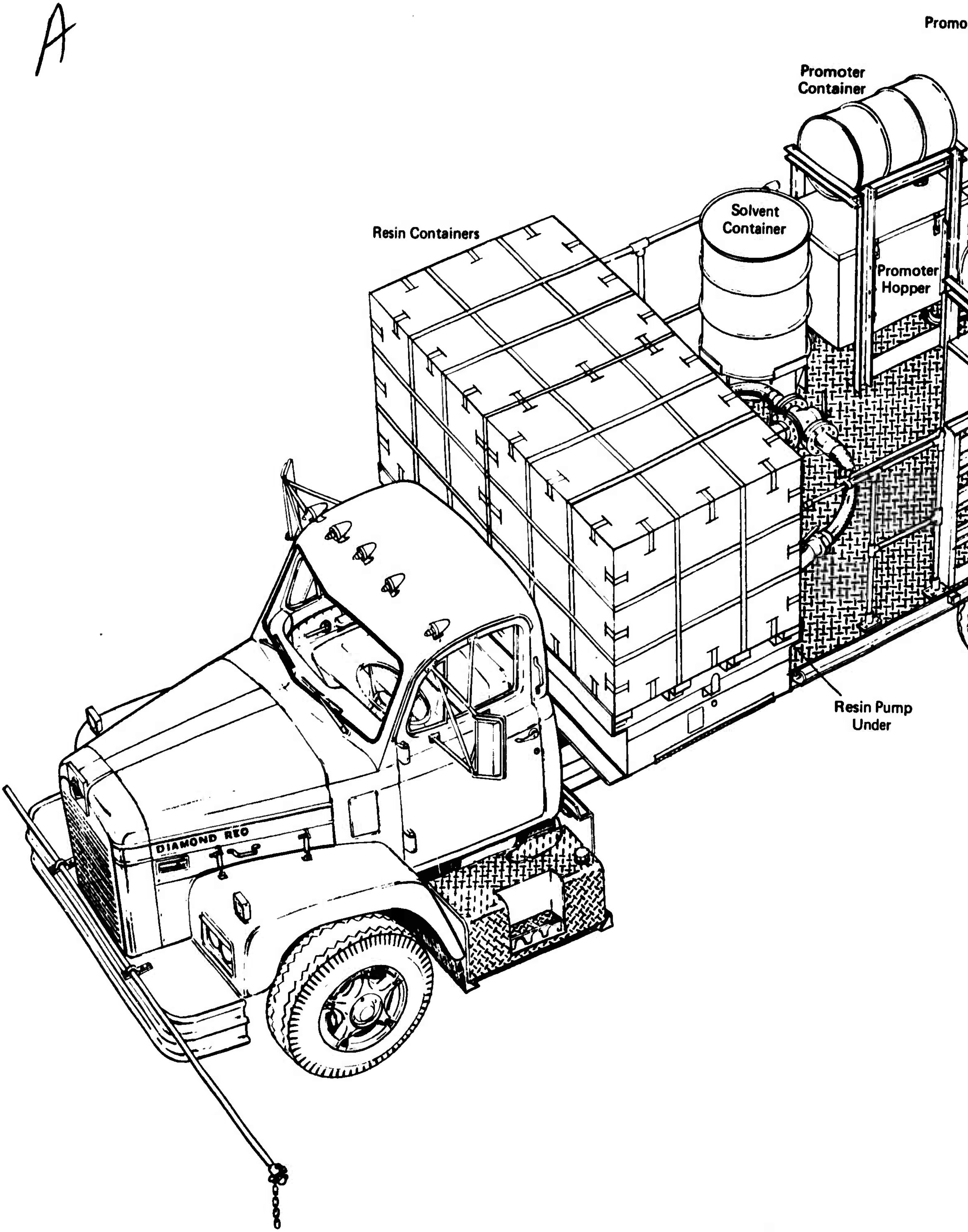
Promo
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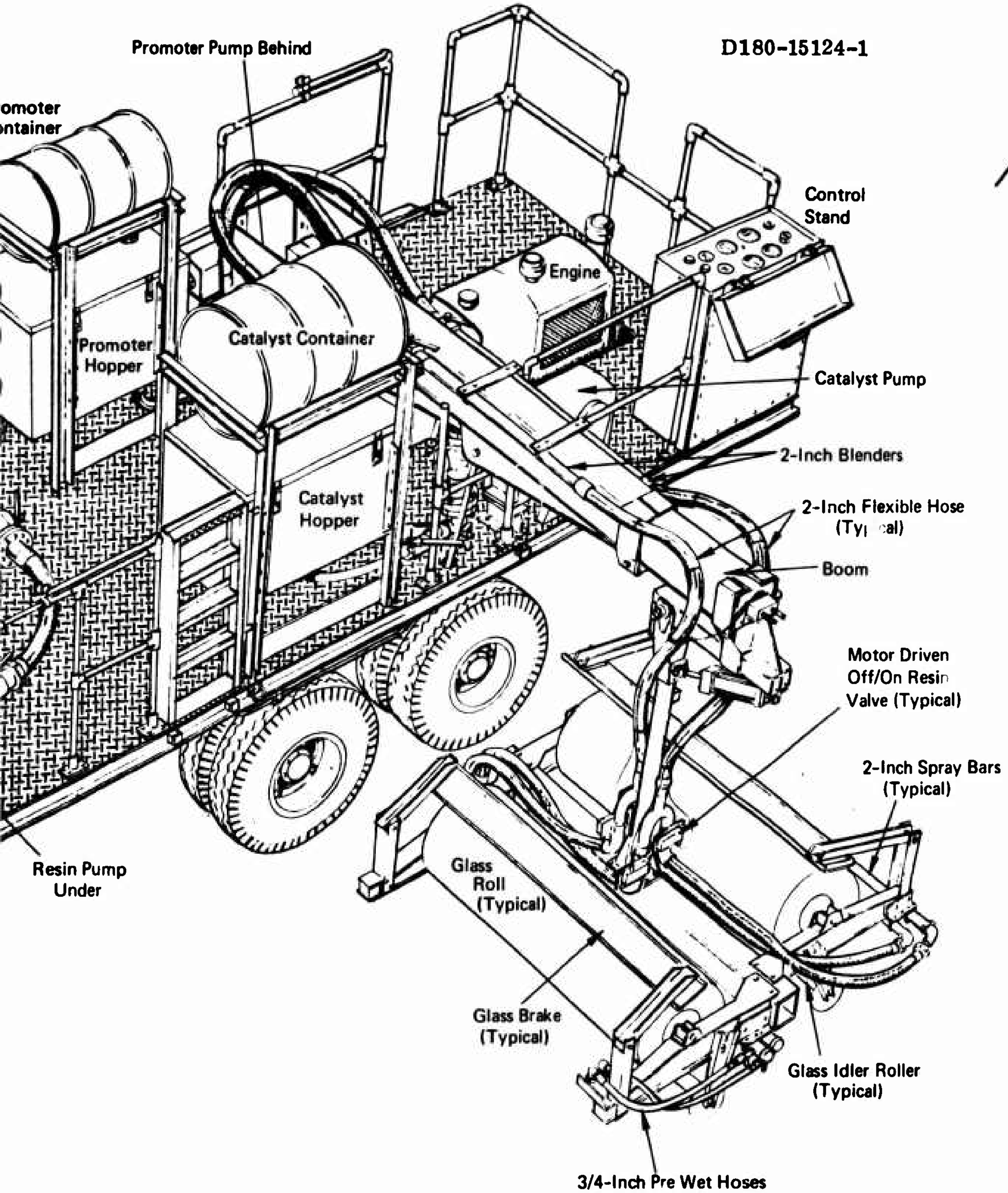


Figure 58: HIGH RATE MATERIALS DISPENSING EQUIPMENT

3.4.2.4 Fluid Dispensing System (Cont)

For the catalyst system, catalyst is drawn from the on-board hopper through a 2 inch suction line. On the discharge side of the pump the catalyst line is reduced to 1-1/2 inch and runs below deck to a "tee" connection. Catalyst flow is split at this point into two 1-1/4 inch lines that run to the two catalyst injection points on one of the 2-1/2 inch resin lines.

The promoter system is similar to the catalyst system with the major exceptions being pump and line size. The system consists of a 3/4 inch suction line and a 3/4 inch pressure line to the "tee" connection. Two 5/16 inch lines run from this point to the injection points on the other 2-1/2 inch resin line.

In the cleaning system, the resin containers are removed and replaced with standard 55 gallon solvent drums. These drums are provided with special adapters for connection to the 3 inch resin suction line dry "quick connect-disconnect" fittings. Solvent may then be drawn from either drum (controlled by the manually operated selector valve) and by means of the resin pump, pumped through the resin system. The catalyst and promoter systems are first drained of any reactive liquids remaining. Sufficient solvent for cleaning is then placed in the respective liquid containers. This solvent may be added using the portable solvent spraygun pump unit and drawing the solvent from the on-board solvent drum. Solvent is then pumped through the systems by means of their respective pumps. Since the catalyst and promoter pumps can be operated independent of the resin pump, these systems may be cleaned separately if desired. After satisfactory solvent flushing, final cleaning is accomplished by delivering air under pressure through each liquid system. An air hose attached to the air supply located on the back of the truck cab is used for this purpose. The air pressure is supplied by the truck air compressor and is controlled by the air valve located on the truck firewall.

Prior to fabrication of the fluid dispensing system three areas of design were considered critical. One, the design of the catalyst plumbing system was critical in order to prevent pump cavitation and consequent erratic catalyst flow particularly at low ambient temperatures. Another was the selection of spraybar nozzles such that resin application to, and coverage of, the fiberglass mat would be adequate for all conditions of resin viscosity. The third area considered critical was blending of high viscosity catalyst with the relatively low in comparison viscosity resin and blending low viscosity promoter with the high in comparison viscosity resin. Adequate blending was required to ensure that when the catalyzed and promoted resin was externally mixed the resultant material would cure evenly and not result in "hot spots" or areas of uncured material.

Investigations and tests were conducted in these three areas and the results used for the design of the high rate fluid system. These areas were also considered critical to the design of the low rate fluid system. Therefore, these tests and investigations were accomplished to provide information for the design of both the high and low rate fluid dispensing systems.

3.4.2.4.1 Catalyst System Design

The worst design condition for the catalyst system was considered to be at maximum flow when the temperature of the catalyst is 40°F. Because the catalyst is thixotropic, its viscosity varies with flow for constant temperatures, therefore conventional viscosity measuring devices are not effective and a special test was devised for determining catalyst viscosity. A positive displacement pump, available from previous programs, in conjunction with plumbing runs that simulated the planned system configuration, was used to pump the catalyst. Although this pump was not a metering type pump it was used to maintain constant catalyst flow in order to eliminate the pulsing effects of a metering pump that could result in erroneous data readings. Catalyst at 40°F was pumped at the maximum required rate and both material output and pressure drops determined. An apparent catalyst viscosity of 3740 centipoises (CPS) was determined from these tests. This value was used for the design of the catalyst system.

3.4.2.4.2 Nozzle Selection

Nozzle selection was based on a series of tests made to evaluate various spray nozzles for capability to provide required flow and fan angles for resin viscosities ranging from 80 to 1600 CPS. A total of 20 different nozzle variations were tested with PPG 5000 SC19-143 resin at 40°F. Five of these were also tested with Hetron 26540 resin at 40°F. Tests included measurement of nozzle output, fan angle, pressure, and evenness of resin distribution. Figure 59 shows a typical nozzle evaluation test. A tendency for the spray pattern to be resin heavy at the edges was noted for all nozzle types tested with increasing pressure and viscosity causing the condition to worsen. The spray pattern was found more even and wider using 26540 resin at 40°F than for the 5000 SC19-143, as would be expected due to the difference in the resin viscosities (720 CPS for 26540 and 1000 CPS for SC19-143) as measured during nozzle testing. Additional nozzle testing was accomplished with resin at 1600 CPS and at a range of viscosities down to approximately 80 CPS. A Spraying Systems 9520 nozzle was found acceptable for spraying both the PPG 5000 SC19-143 and Hetron 26540 resin. A minimum resin viscosity of 80 CPS occurs when the 26540 resin is at 95°F. A Spraying Systems 11015 nozzle (modified by increasing bore size) was found to provide an acceptable spray pattern for the 1600 CPS viscosity resin.

3.4.2.4.3 Fluid Blending

Investigations and tests were made relative to methods of achieving improved resin/catalyst and resin/promoter blending over that used in the On-Fast System. Because both the catalyst and promoter metering pumps deliver their respective fluids in a pulse like manner, these tests were also used to determine the best method of injecting the catalyst and promoter into their respective resin lines. Two methods were considered. One was installing a mixing plenum chamber just forward of the blender. This would provide sufficient volume for an excess of catalyst or promoter material to accumulate prior to blending thus alleviating the pulsing effect of the pumps. The other method consisted of dual injectors. This would essentially halve the amount of catalyst or promoter injected at either point while doubling the frequency of injection thus alleviating the pulsing effect of the pumps.

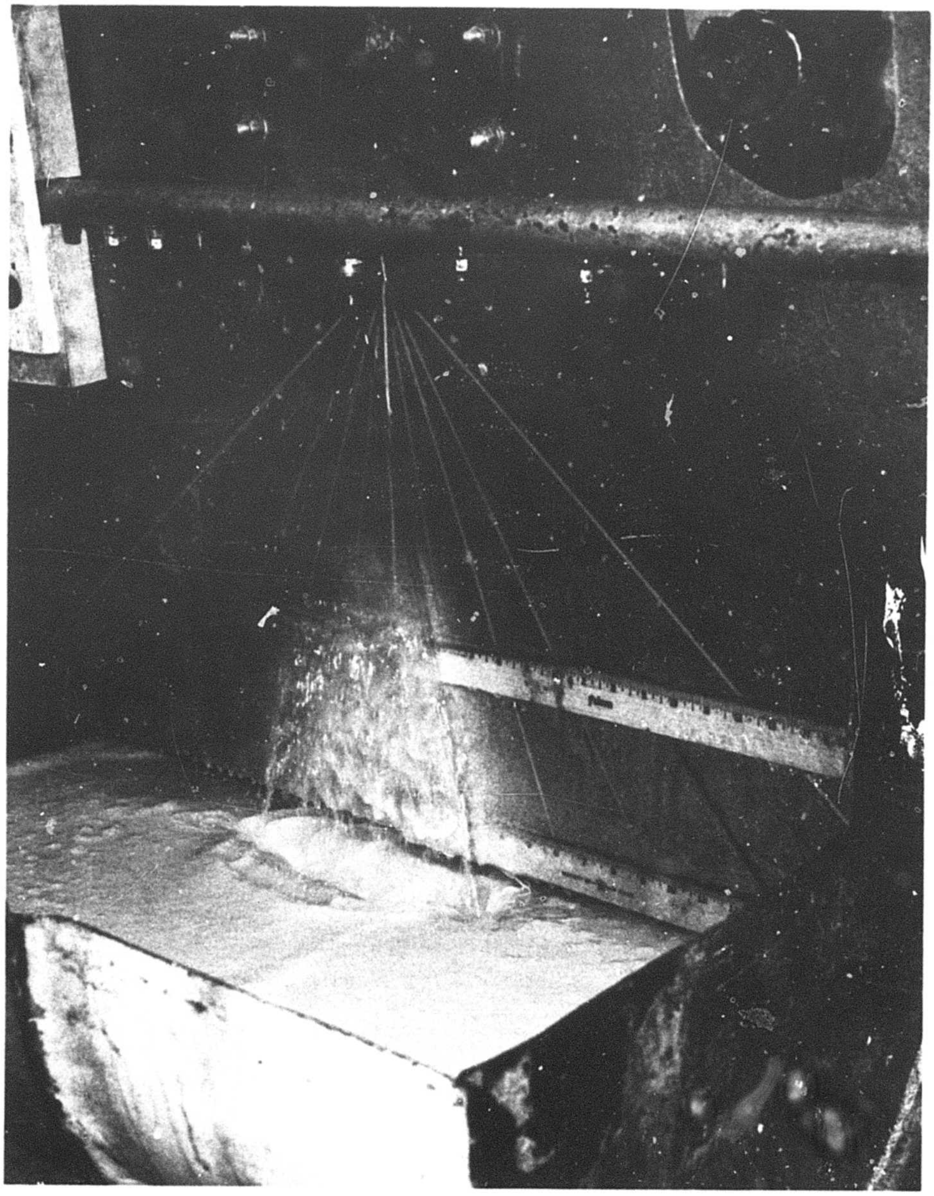


Figure 59 : NOZZLE EVALUATION

3.4.2.4.3 Fluid Blending (Cont)

A review of commercial blenders was made considering both applicability and availability. As a result of this review, a blender (manufactured by Kenics Corporation) was obtained for evaluation. This particular type of blender has no moving parts and consist basically of alternate sections of right hand and left hand helixes and has been used successfully in industry to mix a variety of materials with viscosities ranging up to a pastelike consistency. This 21 element "Kenics" blender was tested at various flow rates at resin temperatures from 27^{o}F (ambient) to 95^{o}F. Resin/catalyst and resin/promoter were blended using single and dual injectors both with and without a mixing plenum chamber. Adequacy of blending was checked by measuring the gel time of samples taken from various points along the spray pattern and also by checking a series of line samples to verify the streamwise distribution. Except for some streakiness at the 8% setting of the catalyst pump with one injector and no mixing plenum chamber, all blending was acceptable with variation in gel times averaging approximately 13%. Figure 60 shows a schematic of the test setup. Based on satisfactory performance of the Kenics type blender they were installed in the high-rate fluid dispensing system. The testing also indicated that dual injection in conjunction with a blender was the most satisfactory combination for blending in the high-rate system.

3.4.2.4.4 Fluid System Calculations

The catalyst and resin are highly viscous when at 40^{o}F, therefore the design of the plumbing system between the supply containers and the pump so as to avoid pump cavitation and consequent erratic flow was of prime consideration. Plumbing downstream of the pumps was of equal important to ensure adequate pressure capability of the pump and other system components. Pressure drops were computed using the following relationship taken from Crane Company, Technical Paper No. 410 (Reference 17) for laminar flow in straight pipe:

$$\Delta P = \frac{.000273\ \mu LQ}{d^4}$$

Where:

ΔP = Pressure differential in PSI

μ = Viscosity in centipoise (CPS)

L = Pipe length in feet

Q = Flow in gallons per minute

d = Pipe inside diameter in inches

Components of the system such as valves and fittings were generally assigned an equivalent length of straight pipe based on test exerpeince and recommendations in Reference 17. The 40^{o}F viscosity assigned to the catalyst was 3,740 cps based on pressure measurements taken during pumping tests at the approximate maximum

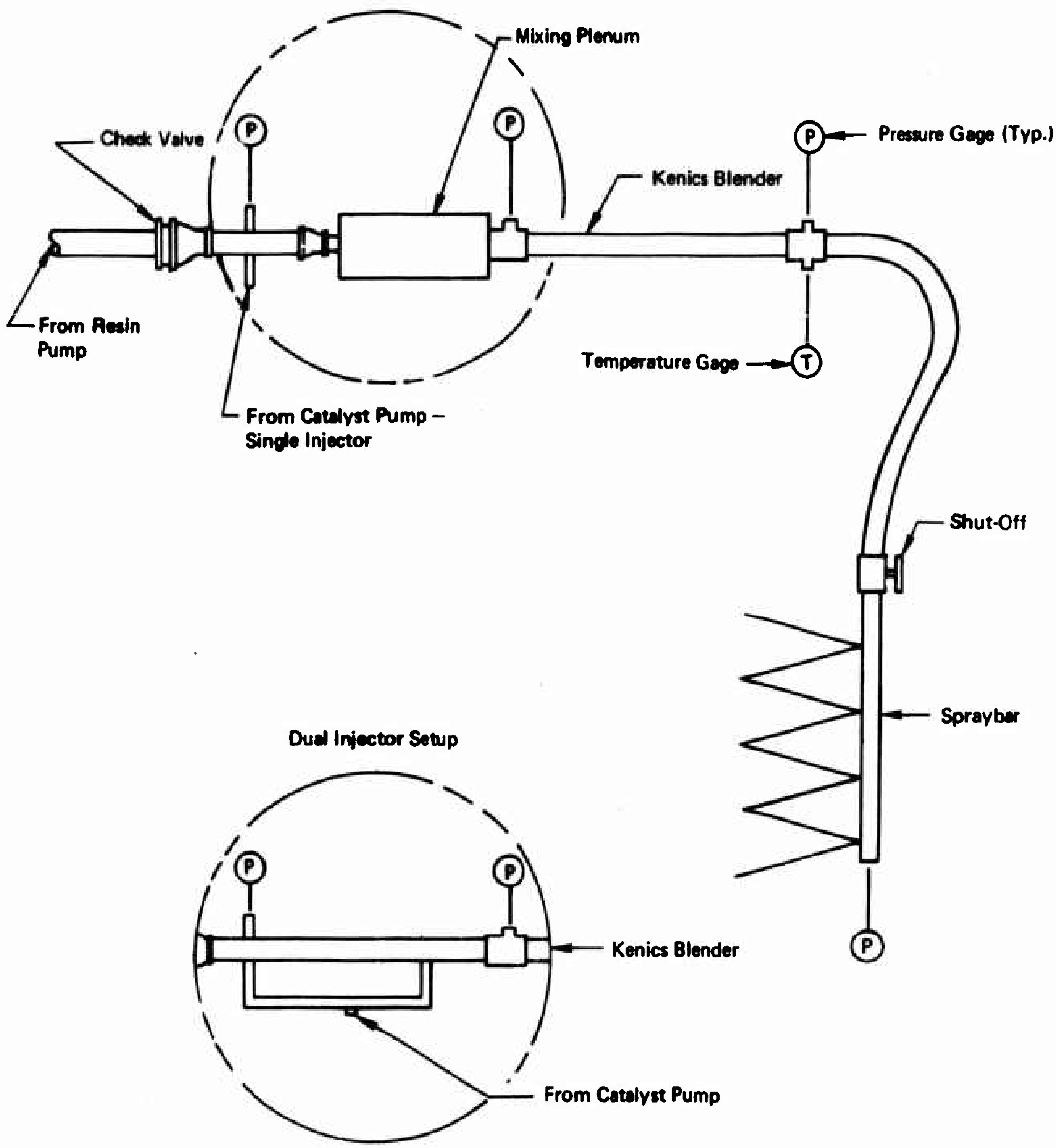


Figure 60: BLENDING TEST SETUP

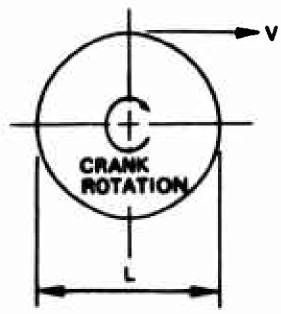
3.4.2.4.4 Fluid System Calculations (Cont)

required flow. A typical calculation is as follows for the catalyst system. Since the catalyst pump is a reciprocating single piston type, peak flow is greater than the average flow as follows:

For a reciprocating piston of diameter d and stroke L

$$\text{Piston Area, } A = \frac{d^2 \pi}{4}$$

$$\text{Pump displacement, } D = \frac{Ld^2 \pi}{4}$$



Operating at a stroking speed S; (RPM)

$$\text{Average flow } Qa = SD = \frac{SLd^2 \pi}{4}$$

$$\text{Maximum Piston Velocity } V_P = L\pi S$$

$$\text{Peak flow } Q_P = V_P A = \frac{L\pi^2 Sd^2}{4}$$

$$\frac{Qp}{Qa} = \frac{\frac{L\pi^2 Sd^2}{4}}{\frac{SLd^2 \pi}{4}}$$

$$Qp = \pi Qa$$

The n aximum required average flow is 34.6 lb/min

$$\text{The } Qp = \pi Qa = 3.1416 \times 34.6 \text{ lb/min} \times \frac{1}{9.8 \text{ lb/gal}} = 11.09 \text{ gal/min}$$

Therefore ΔP for 3 inch sched. 40 pipe

$$= \frac{(.00273)\ (3,740 \text{ cps})\ (1 \text{ ft})\ (11.09 \text{ gpm})}{3.068^4 \text{ inch}} = .128 \text{ psi/ft}$$

Equivalent length for a double ball check unit based on data is 140 diameters. Equivalent length then is

$$\frac{140 \text{ dia} \times 3.068 \text{ in/dia}}{12 \text{ in/ft}} = 35.8 \text{ ft}$$

3.4.2.4.4 Fluid System Calculations (Cont)

ΔP for double ball check unit = 35.8 ft x .128 psi/ft = 4.58 psi

The pressure drops attributable to other components of the resin and catalyst system were similarly computed.

Because the promoter is of low viscosity, (close to that of water) flow is turbulent at the peak flow condition. System pressures were calculated using procedures similar to that described above except that the following formula (Reference 17) was used:

$$\Delta P = \frac{.001294\ fL\rho v^2}{d}$$

Where:

- f = Friction factor
- L = Pipe length in feet
- ρ = Fluid density in pounds per cubic foot
- v = Mean velocity in feet per second
- d = Pipe inside diameter in inches

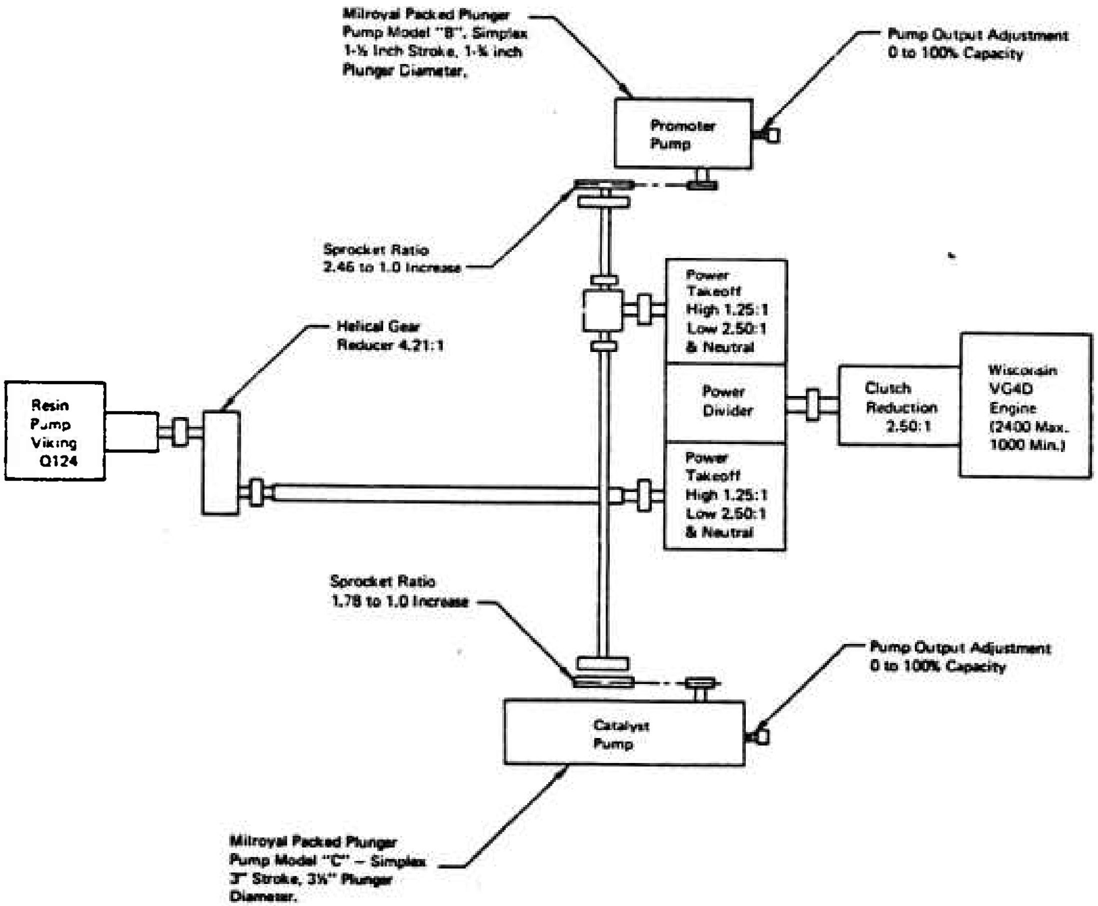
3.4.2.5 Methods for Controlling the Material Dispensing Rates

The overall drive system from engine to the liquid pumps is shown schematically in Figure 61. Detail information on the engine and pump capabilities has been presented in Section 3.4.2.3. Figure 62 shows materials dispensing rate control. Basically, the method for controlling the resin dispensing rate for a given truck ground speed is accomplished by varying the engine rpm for a selected power take-off ratio. Additional variation can be achieved by changing the power take-off ratio. The catalyst and promoter dispensing rates are accomplished in the same manner as noted for the resin, with a constant speed ratio maintained between the resin pump and the catalyst and promoter pumps. This is achieved by use of the power divider and power take-offs (See Figure 61). Further control of the catalyst and promoter pumps output in any speed range is attained by adjustment of the pumps metering control.

The rate of fiberglass dispensing is controlled by truck ground speed. For given pump settings, quantity of liquids dispensed per square foot may also be varied as a direct function of truck speed.

3.4.2.6 Operator Controls and Instruments

The operator controls and instruments for the high-rate surfacer fall into three basic categories: the truck driver's, the on-board materials tender's, and the equipment operator's.



Drive Speed Range	Engine Speed (RPM)	Resin Pump Speed (RPM)	Resin Pump Output (GPM)	Promoter Pump Speed Strokes/Min.	Pro Pump 100% Output (GPM)	Cat. Pump Speed Strokes/Min.	Cat. Pump 100% Output (GPM)
High 13 17 to 1.0	2300	175	109	146	2.03	106	12.3
	2200	167	104	140	1.95	101	11.3
	2000	152	94	127	1.77	92	10.2
	1800	137	84	114	1.59	83	9.2
	1600	121	74	101	1.42	74	8.2
	1400	106	64	88	1.24	65	7.2
	1200	91	54	76	1.06	55	6.1
	1000	76	44	64	0.89	46	5.1
Low 26.34 to 1.0	2400	91	54	76	1.06	55	6.1
	2200	84	49	70	0.97	51	5.6
	2000	76	44	64	0.89	46	5.1
	1800	68	39	57	0.80	42	4.6
	1600	61	34	51	0.71	37	4.1
	1400	53	29	44	0.62	32	3.6

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Figure 61 : PUMP DRIVE SYSTEM, HIGH RATE SURFACER

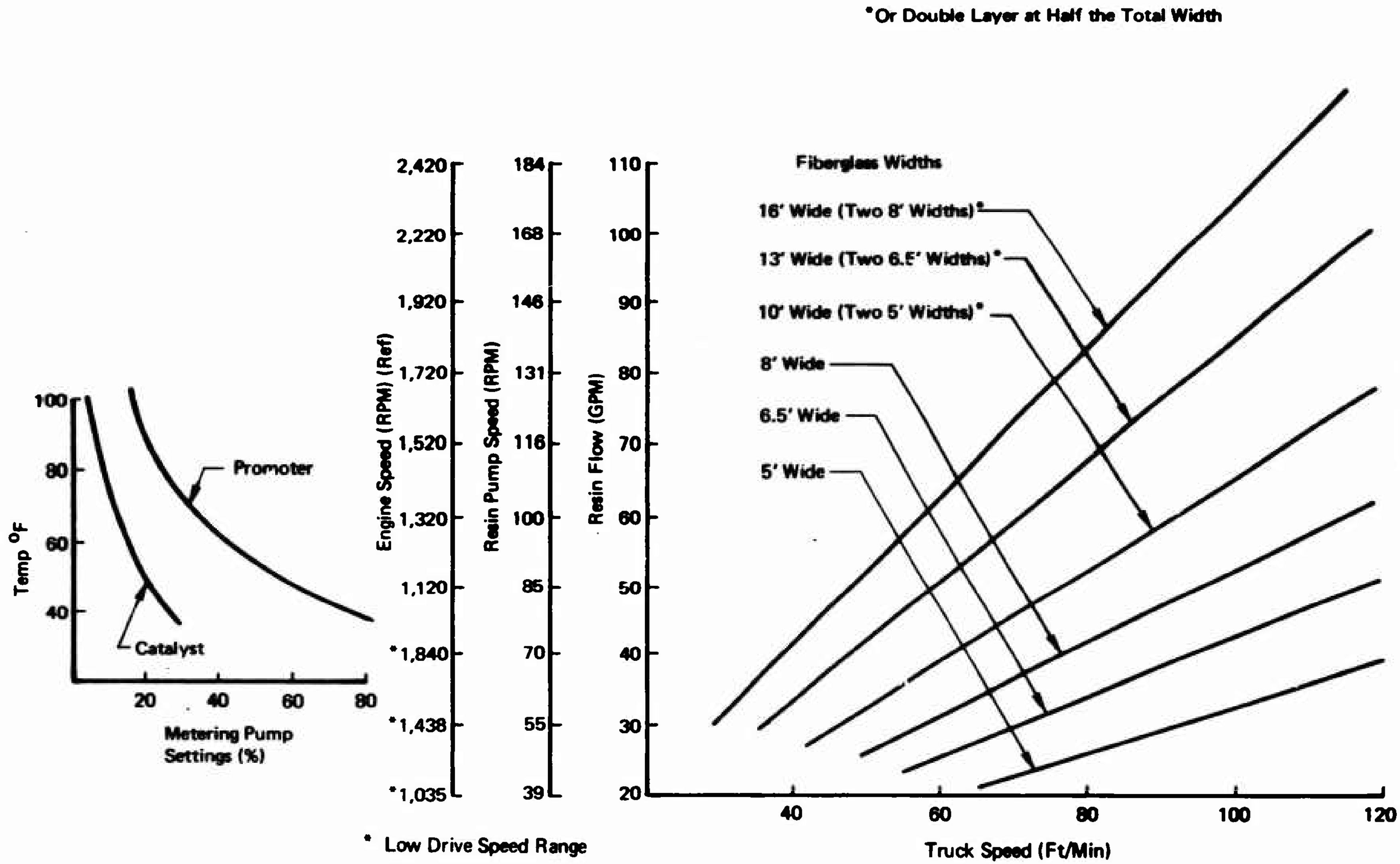

Figure 62 : ***MATERIALS DISPENSING RATE CONTROL, HIGH RATE SURFACER (SC 19–143 RESIN)***

3.4.2.6 Operator Controls and Instruments (Cont)

The truck driver's controls and instruments include the conventional type required to drive the truck and monitor systems during highway operation as well as the additional items required during surfacing operations. These items include slow speed transmission control, slow speed indicator, a guiding aid for maintaining a straight path and desired overlap, signal indicator and "Go-Stop" lights for communication between driver and equipment operator.

The on-board materials tender's controls and instruments consist of a selector value for switching connection to the resin liquid containers. Liquids remaining are monitored by periodic visual observation. Resin quantity remaining is determined by observing the gage marks printed on the resin container cardboard lining. High/low liquid level indicators are provided in the promoter and catalyst hoppers.

The equipment operator's controls and instruments include those required to control and monitor engine and pumps, control the boom and turret, and communicate with the truck driver. A schematic depicting controls and instruments location is shown in Figure 63. Figure 64 shows the equipment operator's instrument panel.

3.4.2.7 System Transportability

For ground transport involving appreciable distance the surfacer with boom and turret would function as a conventional truck and is capable of maintaining normal convoy speeds. All surfacing materials as well as the resin containers would be removed. The fiberglass and resin spraybar support structure would be positioned to the rear of the truck and secured by bolting the vertical support strut to the bracket provided on the truck bed. Items such as special tools, alignment guide and portable solvent spraygun-pump unit would also be stowed on the surfacer. The rolling equipment including tractor, rollers assembly (detached from tractor) and cleaning trough would be carried by a separate truck/flatbed trailer. For local off highway transport between sites the equipment could be moved while in surfacing configuration.

For air transport the surfacer can be carried by C-130 aircraft. The configuration would be as follows: Promoter and catalyst hoppers are removed as is the lower portion of the fiberglass spraybar support assembly. These items as well as the rolling equipment would require an additional aircraft for simultaneous deployment unless an aircraft larger than a C-130 was employed as a carrier.

3.4.2.8 Calculations for Stability

Stability of the high-rate surfacer was of paramount concern due to the requirement for surfacing to the side of the truck particularly on a lateral slope of 20%. Accordingly, thorough analysis was made of this condition. The following paragraphs present a weight and balance summary of this condition and two other critical conditions.

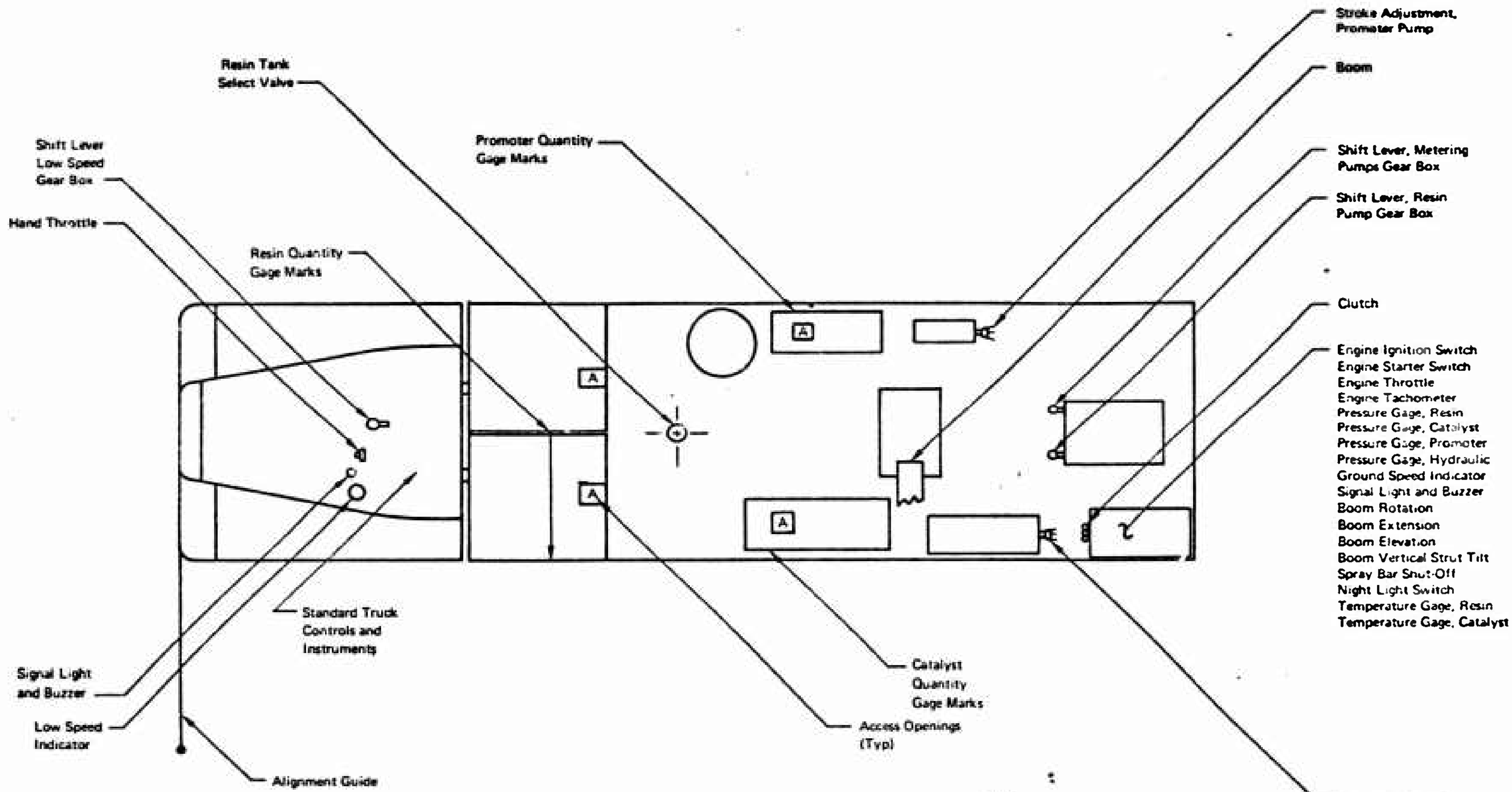

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Figure 63: OPERATOR CONTROLS, HIGH RATE SURFACER

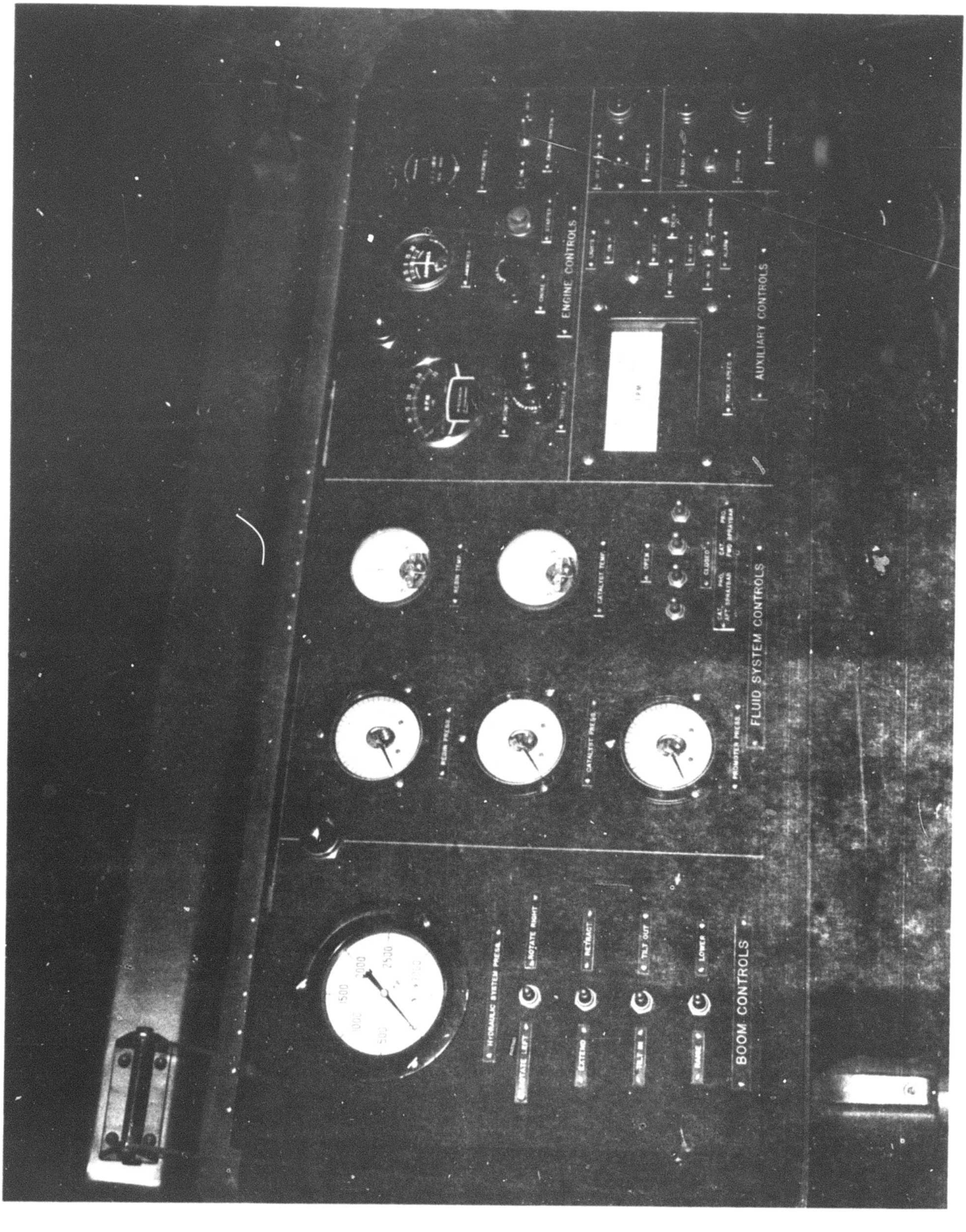

Figure 64 : CONTROL PANEL – HIGH RATE EQUIPMENT

3.4.2.8 Calculations for Stability (Cont)

The high-rate application equipment was analyzed in the three conditions considered to be the most critical because of possible tipping or load distribution. Table 28 shows a tabulation of some of the major items affecting stability. A complete listing of all items has not been shown in order to avoid excessive detail. The three conditions analyzed were:

1) Boom and turret are to the extended position on the left, with 8-foot wide full rolls of glass spaced for 6-in. overlap, with liquid containers on the left all full and with the right resin container empty, promoter drum removed, promoter hopper 1/4-full, and the solvent container empty. The truck is on a 20% slope to the left. A typical type of calculation is shown in Figure 65.

2) Boom and turret are to the extended position on the right, with 8-foot wide full rolls of glass spaced for 6-in. overlap, with liquid containers on the right all full, the left resin container empty, catalyst drum removed and catalyst hopper 1/4-full. The truck is on a 20% slope to the right. A typical type of calculation is shown in Figure 66.

3) Boom and turret are to the rear of the truck with full rolls of glass and with all liquid containers full.

The resultant stabilizing load for condition 1 above is 5,359 pounds.

The resultant stabilizing load for condition 2 above is 8,368 pounds.

The maximum calculated load, including the weight of the truck chassis per condition 3 above, was found to be 36,156 pounds with 25,836 pounds on the rear axles and 10,320 pounds on the front axle. These loads are within the specification limits for the truck (Reference Table 20).

The stability data above was based upon calculated weights and tends to show good stability even in the most extreme conditions. Verification of the calculated data was accomplished by performing the simple tipping test shown in Figure 67.

The rolling equipment was also analyzed for stability. The worst condition occurs when traversing a 20% side slope with the roller assembly on the low side and raised from the surface. However, even this situation did not appear critical as counterbalancing was required to alleviate asymmetrical loading on the tractor lift mechanism. Considering this, a resultant stabilizing load of 2,803 pounds at the centerline of the tractor was calculated as is illustrated in Figure 68.

3.4.2.9 Trade-Offs

As previously discussed, basic system concepts and approaches were established at the beginning of the program. Therefore, the trade-offs which were made during the course of the equipment system design were made at the subsystem or component level. The significant trade-offs that were made and the resulting selections are discussed in the following paragraphs.

Table 28: *TYPICAL WEIGHT & BALANCE TABULATION*

Item	Size	Qty	Total (wt/lbs)	C.G. Location			Tipping to Left (Condition 1) 20% Slope to Left – Boom & Glass to Left				Tipping to Right (Condition 2) 20% Slope to Right – Boom & Glass to Right		Moment at STA 0.0 [1]
				Station	Water Line	Buttock Line	RBL+, LBL- 0.9806 BL	-0.1959 WL	Moment Arm to ℄ Left Wheels + or -	Moment at ℄ Left Wheels + or -	Moment Arm to ℄ Right Wheels + or -	Moment at ℄ of Right Wheels + or -	Boom & Glass to Rear (Condition 3)
Resin Tote No. 1	48 x 48 x 51	1	4,025 Full 385 Empty	88	89	R24	+ 23.53	- 17.43	+ 40.91	+ 15,750.35 [2]	+ 6.15	+ 24,753.75 [3]	354,200
Resin Tote No. 2	48 x 48 x 51	1	4,025 Full 385 Empty	88	89	L24	- 23.53	- 17.43	- 6.15	- 24,753.75 [2]	-40.91	- 15,750.35 [3]	354,200
Solvent Drum	56 Gallon	1	661 Full 51 Empty	162	89	R33	+ 32.36	- 17.43	+ 49.74	+ 2,536.74 [4]	+ 14.98	+ 9,901.78 [5]	107,082
Catalyst Drum	55 Gallon	1	587 Full 48 Empty	194	123	L33	- 32.36	- 24.10	- 21.65	- 12,708.55	- 43.07	0 [6]	113,878
Catalyst Hopper	24 x 40 x 30	1	1,254 Full 445 Empty	194	84.5	L33	- 32.36	- 16.56	- 14.70	- 18,433.80	- 50.62	- 32,751.14 [7]	243,276
DMA Drum	30 Gallon	1	269 Full 29 Empty	196	114	R36.5	+ 35.79	- 22.33	+ 48.27	0 [8]	+ 23.31	+ 6,270.39	52,724
DMA Hopper	18 x 40 x 22	1	692 Full 332 Empty	196	82.5	R36.5	+ 35.79	-16.16	+ 54.44	+ 22,973.68 [9]	+ 17.14	+ 11,860.88	135,632
Resin Pump	Q 124	1	475	123	48	L2.3	- 2.25	- 9.40	+ 23.16	+ 11,001.00	- 27.66	- 13,138.50	58,425
Catalyst Pump	Model C	1	675	268	65.5	L38	- 37.26	- 12.83	- 15.28	- 10,314.00	- 59.24	- 39,987.00	180,900
DMA Pump	Model B	1	150	255	63	R38	+ 37.26	- 12.34	+ 59.73	+ 8,959.50	+ 14.79	+ 2,218.50	38,250
Power Plant	VG4D	1	595	312	63	0	0	- 12.34	+ 22.47	+ 13,369.65	- 22.47	- 13,369.65	185,640
Glass Roll No. 1	8 ft x 250 ft	1	800	356	20	L105	- 102.96	- 3.91	- 72.05	- 57,648.00	+ 72.06	+ 57,648.00	284,800
Glass Roll No. 2	8 ft x 250 ft	1	800	393	20	L195	- 191.21	- 3.91	- 160.31	- 128,248.00	+ 160.31	+ 128,248.00	314,400
Crane Turret	PC-55	1	1,50[illegible]	239	88	0	0	- 17.23	+ 17.58	+ 26,370.00	- 17.58	- 26,370.00	358,500
Crane Boom	PC-55	1	1,710	307	100	L55	- 53.93	- 19.59	- 38.71	- 66,194.10	+ 38.71	+ 66,194.00	524,970

[1] Sta. 0.0 is the Centerline of the Front Axle.
[2] L.H. Full – R.H. Empty
[3] L.H. Empty – R.H. Full
[4] Empty
[5] Full
[6] Catalyst Drum Removed
[7] Catalyst Hopper ½ Full
[8] Promoter Drum Removed
[9] Promoter Hopper ½ Full

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$$\left.\begin{array}{l}\text{Moment} \\ \text{About "0"}\end{array}\right\} = \Sigma\,(WT_1)\,(\cos\theta)\,(b + RBL_1 - WL_1 \tan\theta) + \Sigma\,(WT_2)\,(\cos\theta)\,(b - LBL_2 - WL_2 \tan\theta)$$

$$= \Sigma\,(WT_1)\,(34.81 + .9806\,RBL_1 - .1959\,WL_1) + \Sigma\,(WT_2)\,(34.81 - .9806\,LBL_2 - .1959\,WL_2)$$

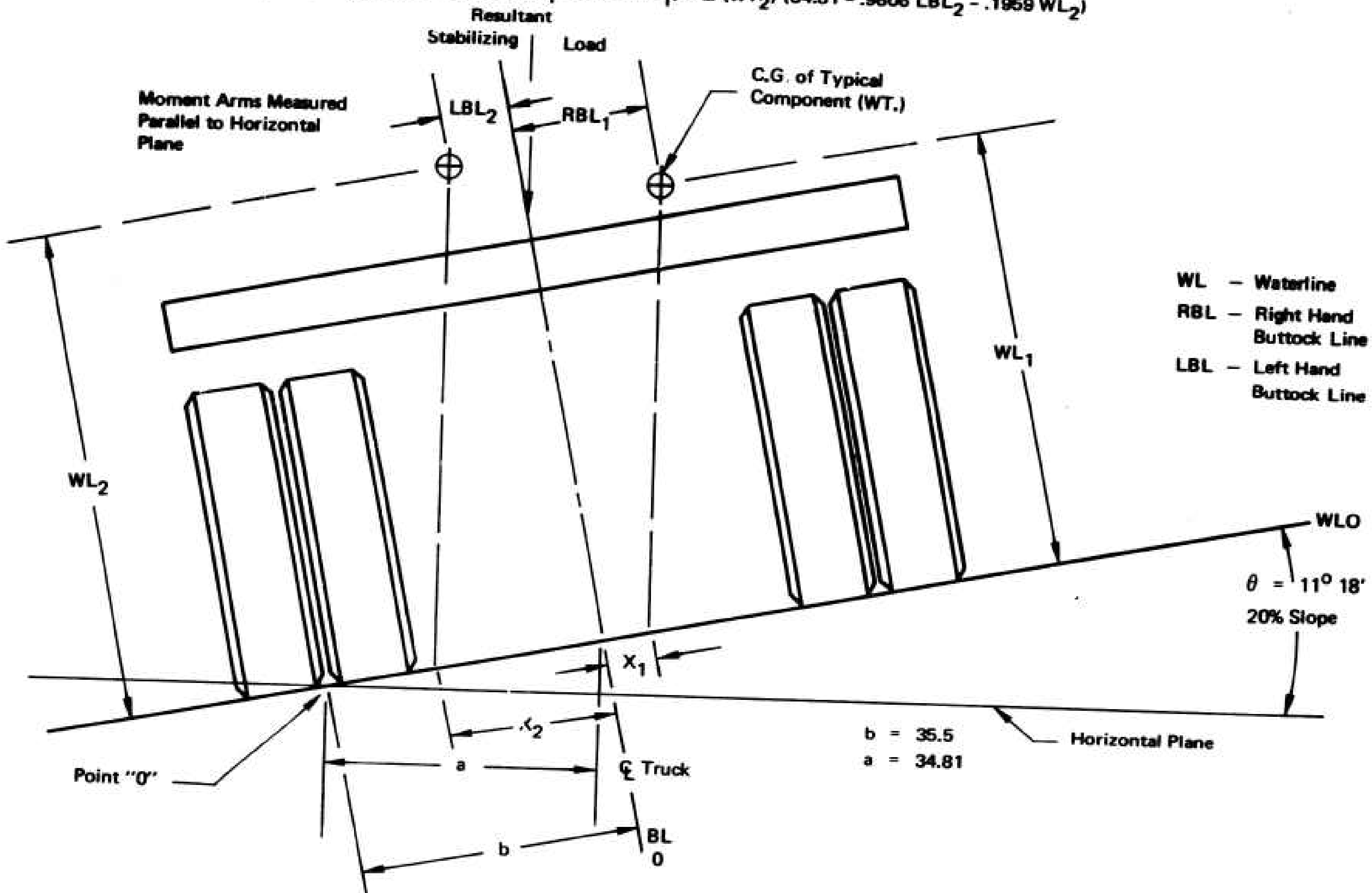


Figure 65 : *TYPICAL STABILITY CALCULATION – SURFACING TO LEFT ON SLOPE*

$$\left.\begin{array}{l}\text{Moment}\\ \text{About "0"}\end{array}\right\} \begin{array}{l} = \Sigma\,(WT_1)\,(\cos\theta)(-b + RBL_1 + WL_1 \operatorname{Tan}\theta) + \Sigma\,(WT_2)\,(\cos\theta)\,(-b - LBL_2 + WL_2 \operatorname{Tan}\theta) \\ = \Sigma\,(WT_1)\,(-34.81 + .9806\,RBL_1 + .1959\,WL_1) + \Sigma\,(WT_2)\,(-34.81 - .9806\,LBL_2 + .1959\,WL_2) \end{array}$$

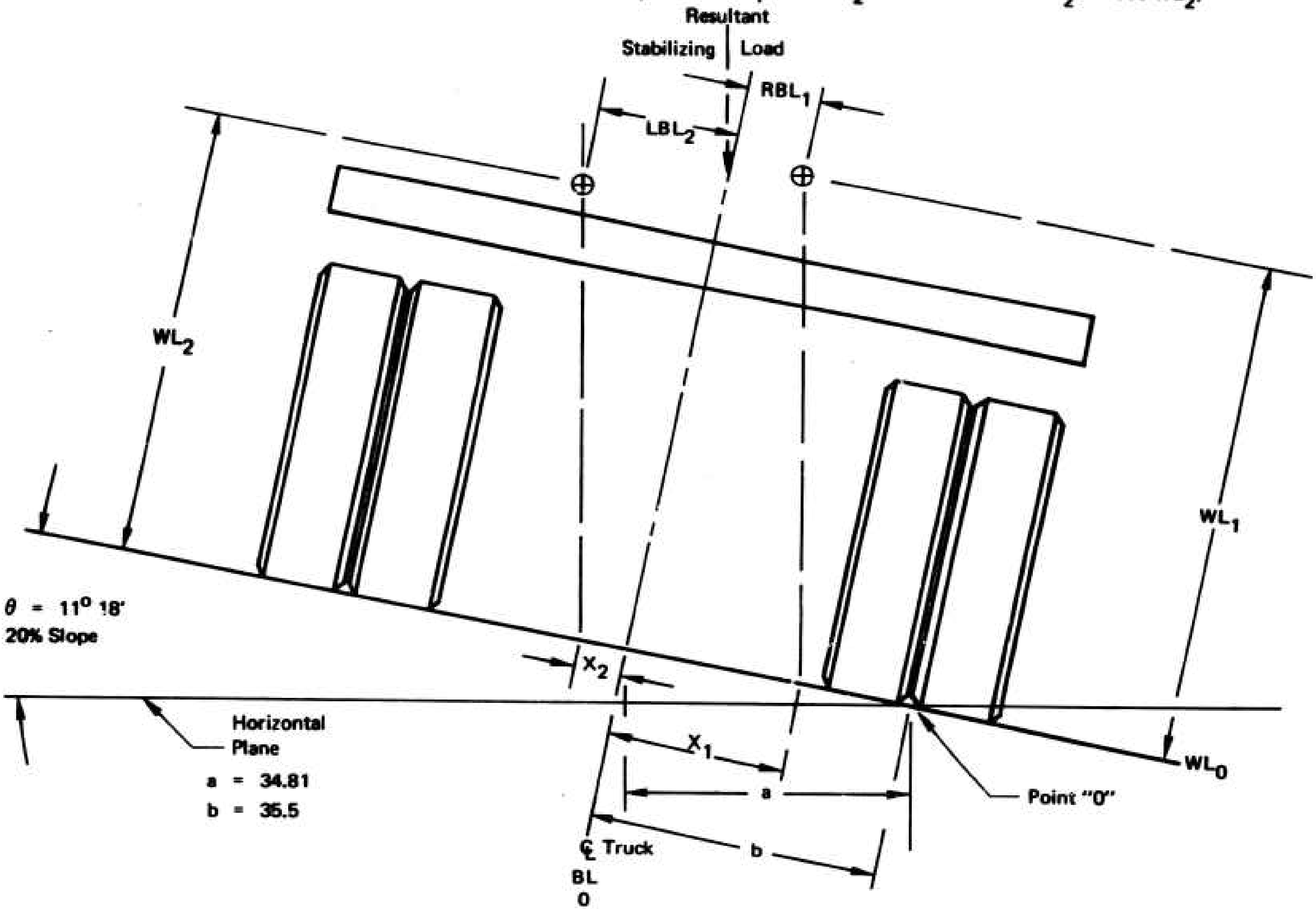


Figure 66 : *TYPICAL STABILITY CALCULATION – SURFACING TO RIGHT ON SLOPE*

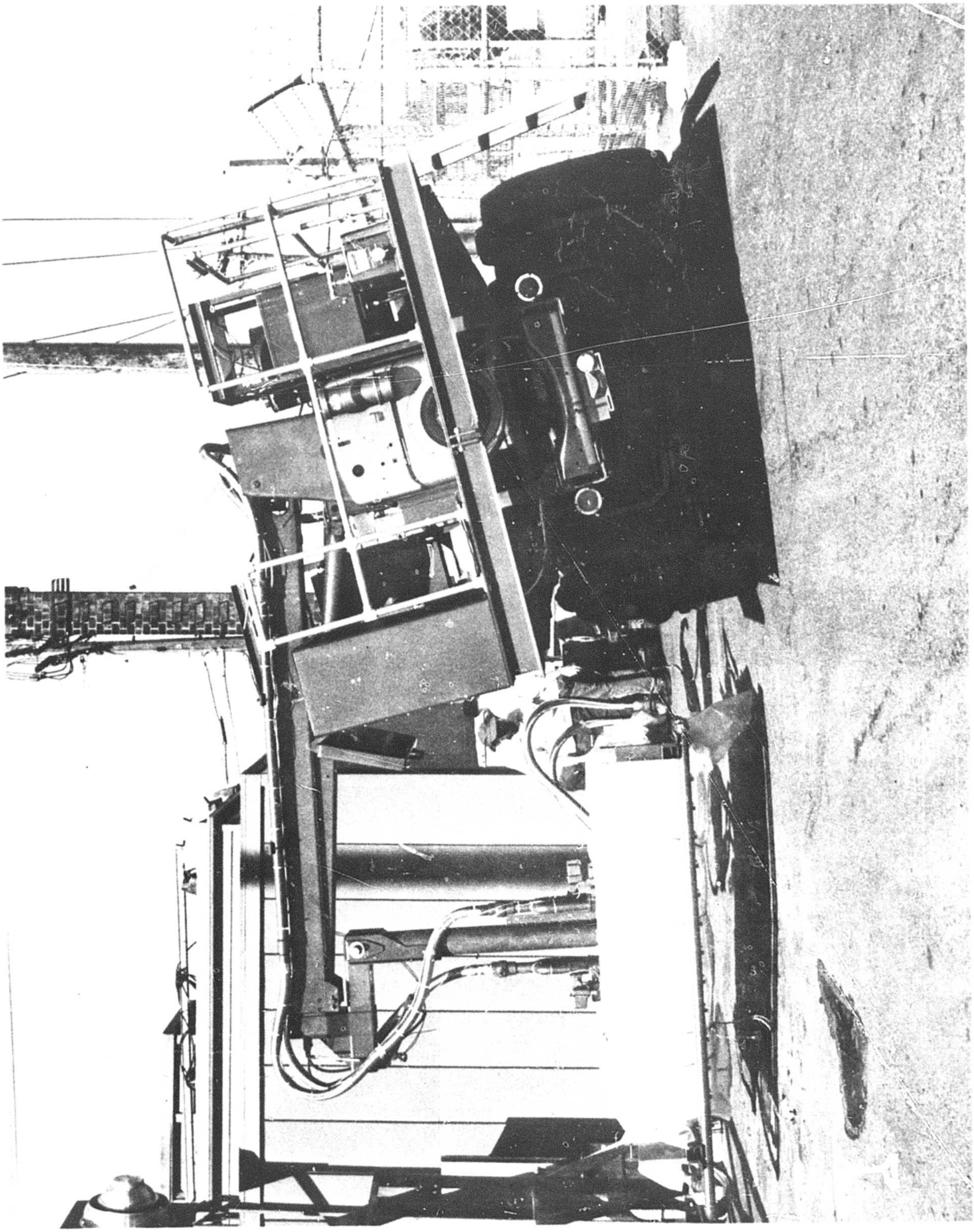
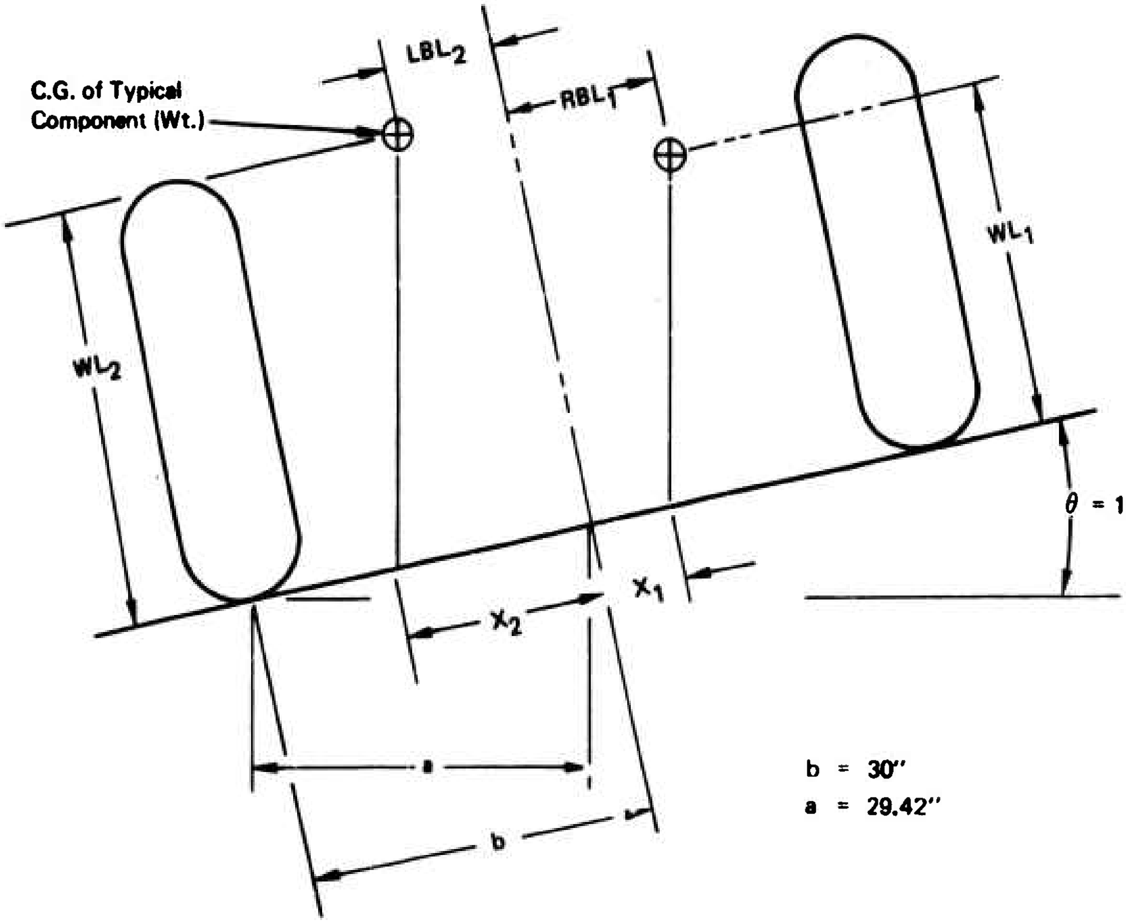


Figure 67 : TIPPING TEST – HIGH RATE EQUIPMENT

Assumptions:

Tractor is on a 20% Slope to the Left Rollers are Elevated.

Tractor is Ford 2000



Moment About $= \Sigma(WT_1)(\cos\theta)(b + RBL_1 - WL_1 \tan\theta) + \Sigma(WT_2)(\cos\theta)(b - LBL_2 - WL_2 \tan\theta)$

$= \Sigma(WT_1)(29.42 + .9806\ RBL_1 - .1959\ WL_1) + \Sigma(WT_2)(29.42 - .9806\ LBL_2 - .1959\ WL_2)$

Equivalent Righting Load at ℄ Tractor at Axle Height = 2803 Lbs.

Figure 68: ROLLING EQUIPMENT BALANCE DATA

3.4.2.9 Trade-Offs (Cont)

A modified commercial boom and turret, hydraulically actuated was selected over a specially designed and fabricated equivalent for support and positioning of fiberglass rolls and resin spraybars. The modified commercial article was selected on the basis of minimum development and history of satisfactory operation of such equipment.

Large capacity r[illegible]ers for the on-board containment of promoter and catalyst were se[illegible]er both standard drum containers and small manifolded containers. The large capacity hoppers on NCEL's recommendation were evaluated and selected on the basis of more efficient use of manpower, simplified gaging for materials remaining determination, improved safety, and greater surfacing efficiency. It should be noted that the hoppers are filled from standard promoter and catalyst drums. If desired, full drums can be mounted above the hoppers thus allowing greater surfacing capacity particularly during cold weather.

Flexible hoses were selected over rigid tubing in conjunction with ball joints for usage in the resin containers to resin pump plumbing system. Flexible hoses were selected on the basis of improved ease of manipulation during line connect-disconnect operations and reduced pressure drop in the flexible hose system.

Liquid level gage marking was selected over float type indicators, weighing scales, pressure gage system, or transparent tubes for determining amount of liquids remaining in containers (resin, catalyst, and promoter). Liquid level markers were selected on the basis of maximum simplicity, ease of reading and minimum development.

Surface rolling equipment utilizing tandem rollers was selected over incorporating a reciprocating feature in the rolling equipment to provide multiple roller passes. This version was selected on: 1) the basis of laboratory results which indicated that diminishing returns on laminate strength occurred if more than two roller passes were employed and thus the addtional complexity of reciprocating equipment was not justified and 2) the basis of similarity to the Rapid-Site equipment which had demonstrated reasonably satisfactory performance.

Boom and turret positioning by controls located directly on the instrument panel was selected over controls positioned on a pendant. Controls located on the instrument panel were selected on the basis of better overall controls integration and simplicity. Also, it did not appear necessary to provide capability to position the boom and turret from more than one operator's station.

Location of the engine clutch control lever on the side of instrument panel was selected over location directly on the clutch assembly. Location on the side of the instrument panel was selected on the basis of better controls integration, simplification of operator's tasks, and minimizing deck clutter.

Special portable spraygun and pump unit for solvent cleaning the deck and equipment was recommended by NCEL, investigated and selected over hand cleanup. The spraygun pump unit was selected on the basis of convenience, less solvent wasteage and more efficient cleaning as had been indicated during field usage of the On-Fast system.

3.4.2.9 Trade-Offs (Cont)

Surface rollers clean up accomplished by positioning the rollers in a solvent trough with roller brushes was selected over cleaning with a spraygun or utilizing throwaway polyethylene sleeves over the rollers. Trough and brushes were selected on the basis of similar Rapid-Site equipment having demonstrated generally satisfactory performance.

3.4.2.10 System Fabrication

Based on the above equipment design and system requirements, fabrication of a high rate equipment system was accomplished. Assemblies such as the roller frame structure (Figure 69) were fabricated concurrent with component procurement and fabrication of the truck bed (Figure 70). Subsequent to truck bed fabrication and installation on the carrier vehicle, major components such as engine (Figure 71), turret (Figure 72), and boom (Figure 73) were installed on the truck bed and assembly of items such as the control stand (Figure 74) accomplished.

Checkout of the resin, catalyst, and promoter pumps was accomplished prior to installation. The planned plumbing runs on both the inlet and outlet sides of the pumps were simulated for this checkout procedure. Pump settings versus output were established for the delivery rates required and system pressures were verified. All pumps exhibited satisfactory performance including capability of the resin pump to deliver resin with a viscosity of 1,600 cps at the required rate and with adequate pressure for sprayability. After satisfactory checkout of the liquid pumps they were mounted on the truck bed and final installation of the plumbing systems, controls and other miscellaneous items required for systems test accomplished.

3.4.3 DESIGN REQUIREMENTS – LOW RATE EQUIPMENT SYSTEM

The basic requirement for the low rate equipment system was the same as for the high rate equipment system except for surfacing rate and carrier vehicle. Design and fabricate an equipment system capable of applying the surfacing materials on previously prepared surfaces such that a continuous, waterproof, load bearing surface would be obtained. In addition the low rate equipment system was designed to the following specific requirements.

Number of operating personnel: The system shall be capable of being operated with a military crew of not more than 5 personnel functioning without external support other than delivery by others to the work area vicinity the following items: power unit fuel, lubricants, and surfacing materials necessary to apply the specified surface covering.

Surfacing characteristics: The system shall have the capability for applying the liquid materials at various flow rates and for dispensing various weights of fiberglass matting so that different weights of surfacing can be applied over various subgrades to provide a final surface coating compatible with the particular soil properties and intended usage. A multilayer laminate is permissible to attain the specified total surfacing weights. Impervious soils may require application

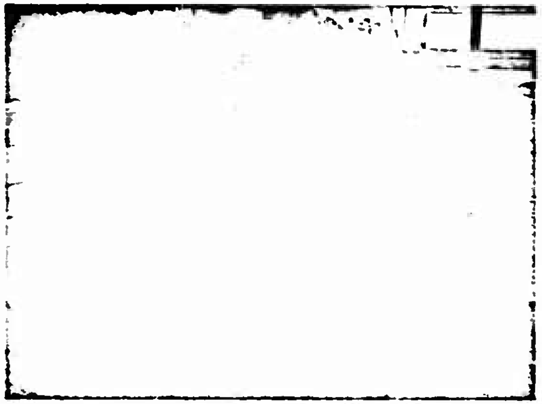


Figure 69: ROLLER FRAME ASSEMBLY

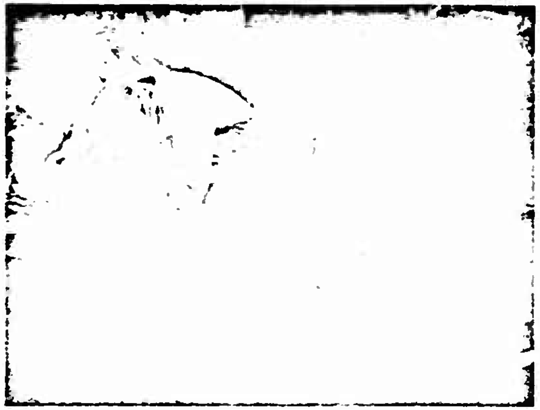


Figure 70: TRUCK BED FABRICATION

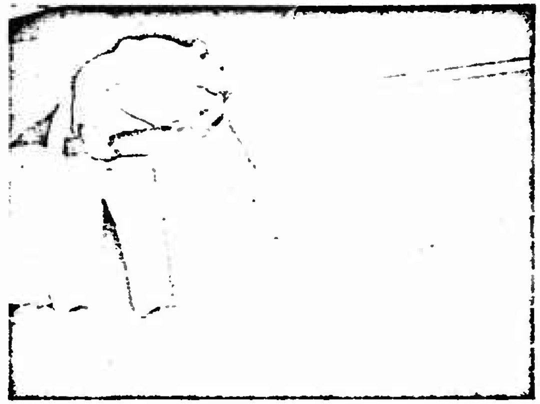


Figure 71: ENGINE INSTALLATION

Figure 72: TURRET INSTALLATION

Figure 73: BOOM INSTALLATION

Figure 74: CONTROL STAND FABRICATION

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HIGH RATE EQUIPMENT SYSTEM FABRICATION

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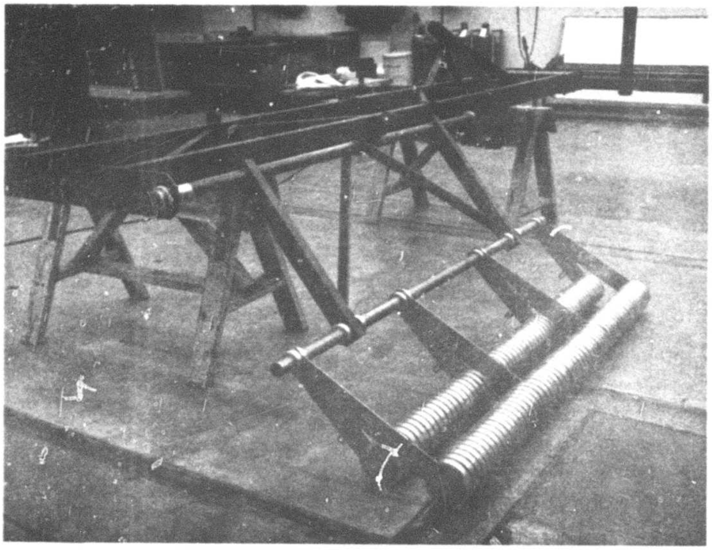


Figure 69: *ROLLER FRAME ASSEMBLY*

Figure 70: *TRUCK BED FABRICATION*

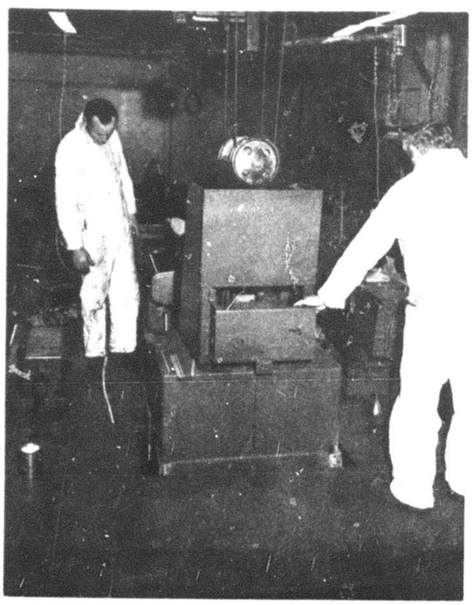


Figure 72: *TURRET INSTALLATION*

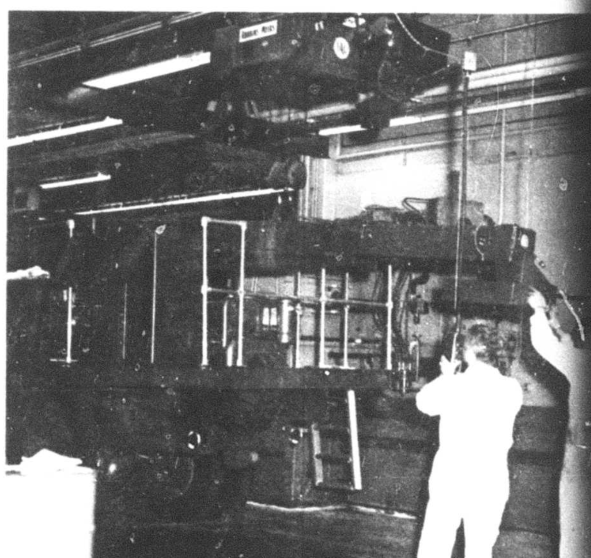
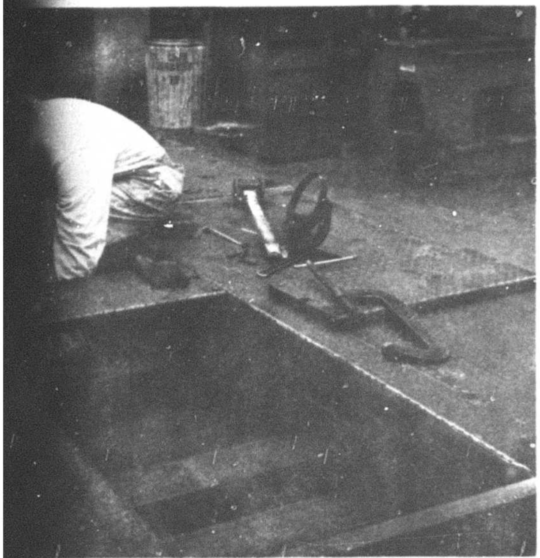


Figure 73: *BOOM INSTALLATION*

B



: TRUCK BED FABRICATION

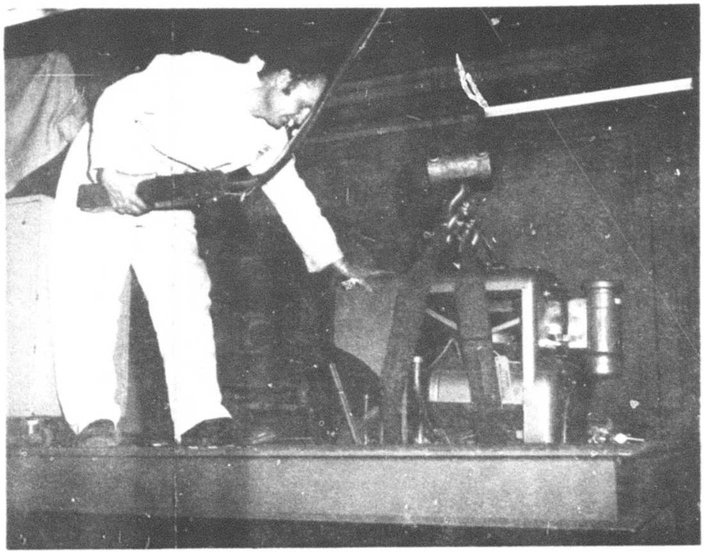
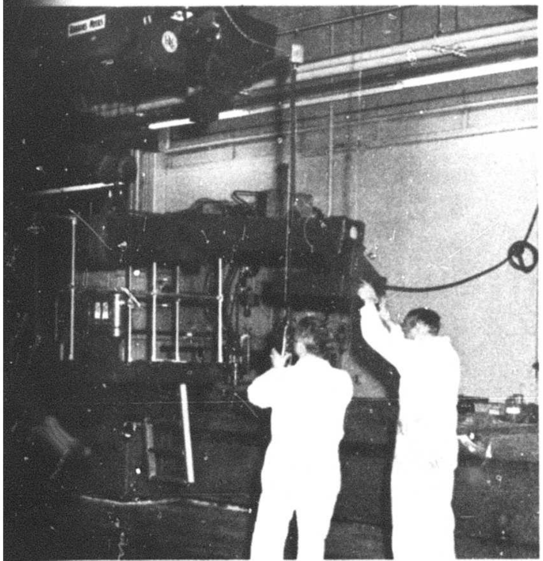


Figure 71 : ENGINE INSTALLATION



3: BOOM INSTALLATION

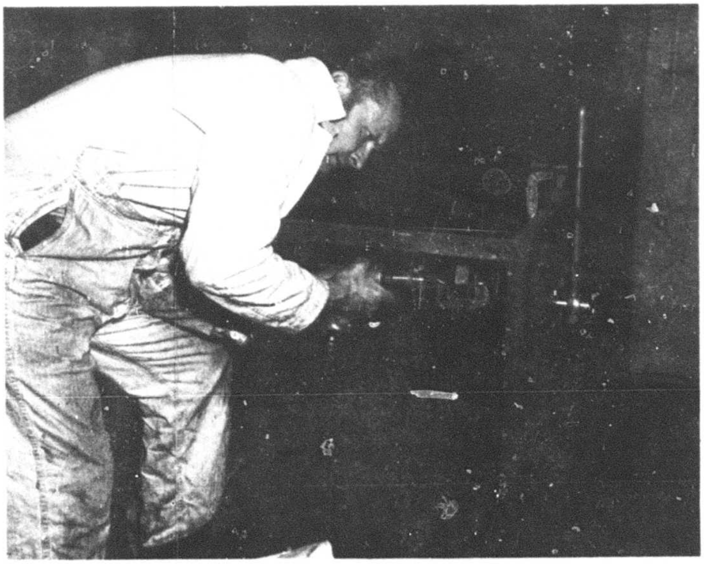


Figure 74 : CONTROL STAND FABRICATION

HIGH RATE EQUIPMENT SYSTEM FABRICATION

3.4.3 DESIGN REQUIREMENTS – LOW RATE EQUIPMENT SYSTEM (CONT)

of smaller amounts of resin in order to achieve proper resin-to-glass ratios than sandy soil; however, the resin-to-glass ratio in the actual cover over the soil shall be the same for any soil type.

Application weights: The application of the surface materials shall provide a 2-pound per square foot surface which may be applied in 2 layers each at 1 pound per square foot or if feasible in 1 layer at 2 pounds per square foot. The application weight of 2 pounds per square foot is nominal; the optimum weight is that at which the fiberglass is neither resin-starved nor resin-rich. By varying the fluid pumping rate, ground speed or spray coverage rate to produce the desired surface, the system shall be capable of applying a variable surface covering weight up to and including 4 pounds per square foot with multilayer laminates using different mat weights.

Application areas: The system shall be capable of applying the surfacing materials specified above on areas specified above and also on areas such as revetments, earth-covered shelters, bunkers, dikes, shelter roofs and similar areas. The system shall be capable of operation on rectangular, oval, circular or irregularly shaped area surfaces.

1) Level surfaces

2) Vertically curved surfaces

3) Sloped surfaces

4) Uneven surfaces

Application rates: The system shall be capable of completing 2 pounds per square foot of polyester resin fiberglass at the rate of 2,000 square feet per hour for not less than 6 continuous hours. The surfacing shall continue for the specified 6 hours without necessity for interruption of the surfacing operations for equipment adjustments, cleaning, preparation, processing, preventative or corrective maintenance, or repair.

Trailer mounted: The system shall be mounted on a trailer, such as M794 or XM525, and have a base frame structure which has 4-way forklift provisions for the [illegible]ation equipment components as well as providing a stable base for the pu[illegible] it when resting on the ground or when being transported on, or operating fro[illegible]icles other than the trailer.

Trailer: The trailer used as part of the application system equipment items shall be designed and constructed in accordance with MIL-M-008090E for the mobility type and group applicable to its use.

Mobility: The system shall have the mobility of the carrier trailer unit. Mobility or flotation improvement efforts shall be limited to wheel and tire revisions or replacements.

3.4.3 DESIGN REQUIREMENTS – LOW RATE EQUIPMENT SYSTEM (CONT)

Spraybar assembly: The system shall dispense the fluid surfacing materials, properly mixed and blended, by means of a manually held spraybar assembly at any desired rate up to at least 55 pounds per minute.

Spray radius: The system shall permit spraying the resin material throughout a semicircular area having a radius of not less than 50 feet without moving or relocating the pumping unit.

Fluid system: The system shall incorporate an external catalyzation method such that the combining of components which brings about the curing of the resin takes place beyond the discharge nozzles of the spraybar assembly.

Yoke-type adapters: The system shall include a yoke-type adapter for unrolling and emplacing the fiberglass matting onto the ground, and the yoke-type adapter shall be capable of accommodating fiberglass up to 5 feet wide as well as the width(s) selected by the contractor. The adapter shall be capable of being attached to and towed by a standard military vehicle furnished by others, or of being pulled by operating personnel. A special tool for cutting fiberglass may be considered for more efficient operation.

Material supply and replenishment: The system shall employ a liquid material supply and replenishment method designed to facilitate loading and handling and to reduce materials wastage.

Cleaning and flushing: The system shall have an integral cleaning and flushing system, including separate solvent storage, on the trailer, which can circulate solvent through the entire application equipment fluid system to thoroughly clean and remove any liquid residue which might otherwise solidify within the system lines or components. On-board waste storage shall be provided.

Component completeness: The system shall be complete and all items such as suction hoses, flushing manifolds and special supply container fittings necessary to apply the surfacing and maintain the application equipment shall be included and storage provisions for these components shall be a basic part of the pumping unit.

3.4.4 LOW RATE EQUIPMENT SYSTEM DESIGN

The low rate equipment was designed and fabricated based on the performance/ design requirements discussed in the previous section. Items considered critical to the low rate equipment system along with the factors and other considerations leading to their selection are discussed in the following paragraphs. Critcal calculations for the selected items are also included in the discussion.

3.4.4.1 Configuration

The initial configuration selected for the low rate equipment has previously been shown in Figure 39. The final configuration is shown in Figure 75. The major change is the replacement of the catalyst and promoter drum type containers with the on-board storage containers and the attendant relocation of the solvent drum. These containers are identical in size and incorporate all the features as those of the high rate equipment system. These "hopper" type containers are used for reasons previously noted and to provide commonality between both equipment systems.

3.4.4.2 Placement of Components

A full scale space mockup of the removable materials dispensing equipment platform was constructed prior to final component selection. The mockup shown in Figure 76 contains simulations of major items of the materials dispensing equipment (engine, drive train, resin pump, catalyst and promoter pump, control stand, and hose reel). One feature evident in the mockup is the weatherproof enclosure completely surrounding the equipment platform. This feature was eliminated from further design consideration due to its hampering effect on overall equipment operation. In addition, visibility provided for the equipment operator was severely reduced. To achieve maximum personnel efficiency and convenience the weatherproof enclosure was replaced with guard rails at critical areas and protective covers were supplied for the control stand and engine.

3.4.4.3 Component Characteristics and Selection

The major components of the low rate equipment system are the trailer, the components of the removable materials dispensing equipment platform (power plant and liquid pumps), fiberglass dispensing yoke, and the fiberglass rolling equipment (fiberglass roller and roller cleaning tank). As was the case with the high rate equipment component selection commercially available items were selected wherever possible. Those items not commercially available such as the trailer, the fiberglass dispensing yoke and rolling equipment were designed based on previous equipment systems. A discussion of the factors and other considerations leading to the component selected or design approach used is presented in the following paragraphs.

3.4.4.3.1 Trailer

Prior to designing the trailer provided, a review of military inventory trailers was accomplished. A trailer was sought that could provide sufficient space and payload capacity for the surfacing materials containers, removable equipment pallet, and had ample storage room for items such as the glass dispensing yoke. This fully loaded trailer was estimated to weigh approximately 18,000 pounds. No suitable military trailer was found that met both the space and weight requirements. Therefore a trailer was designed based on these and other specified requirements (Table 29) and led to the general arrangement and the data used for design shown in Figure 77.

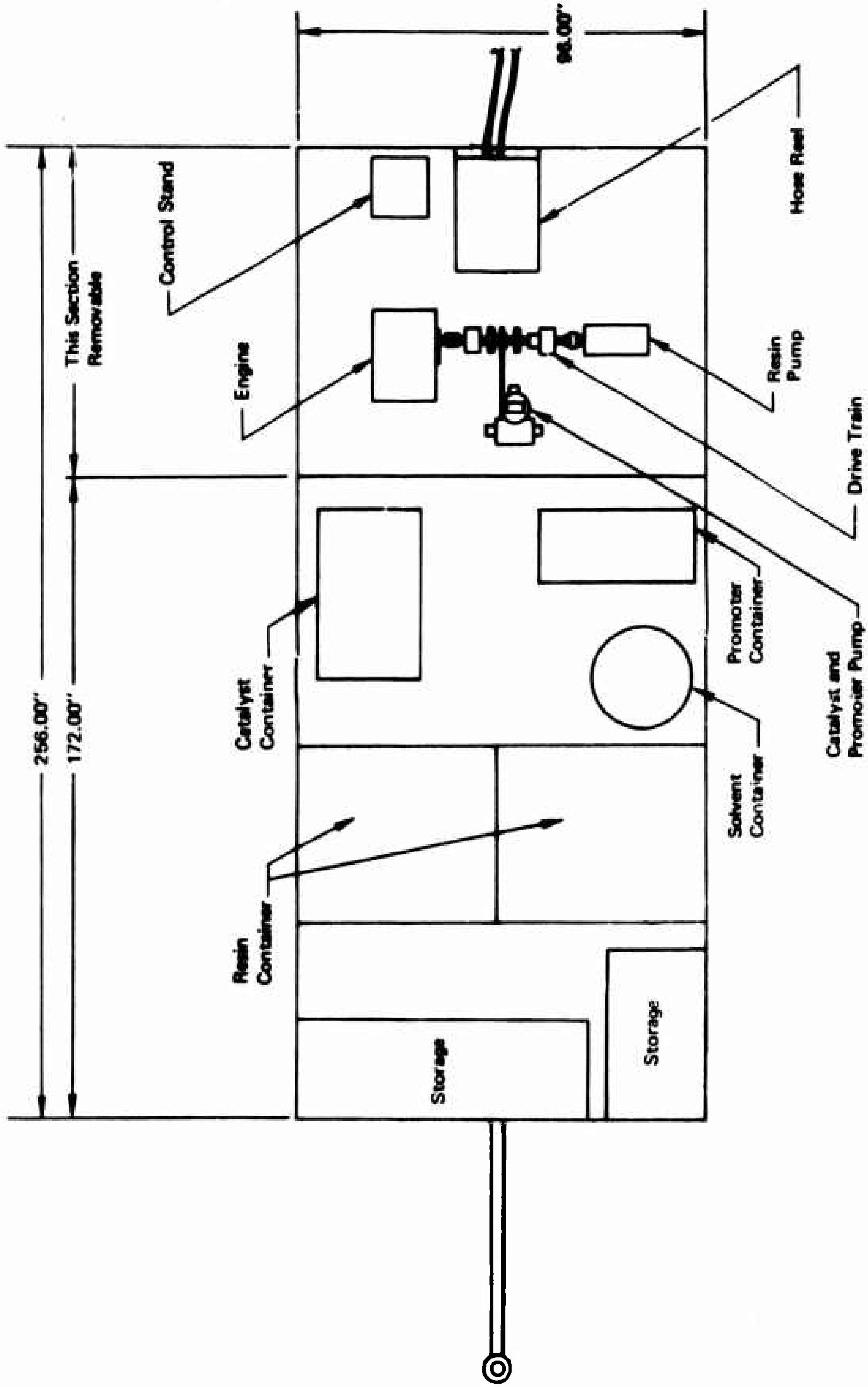


Figure 75: LOW RATE DISPENSING EQUIPMENT CONFIGURATION

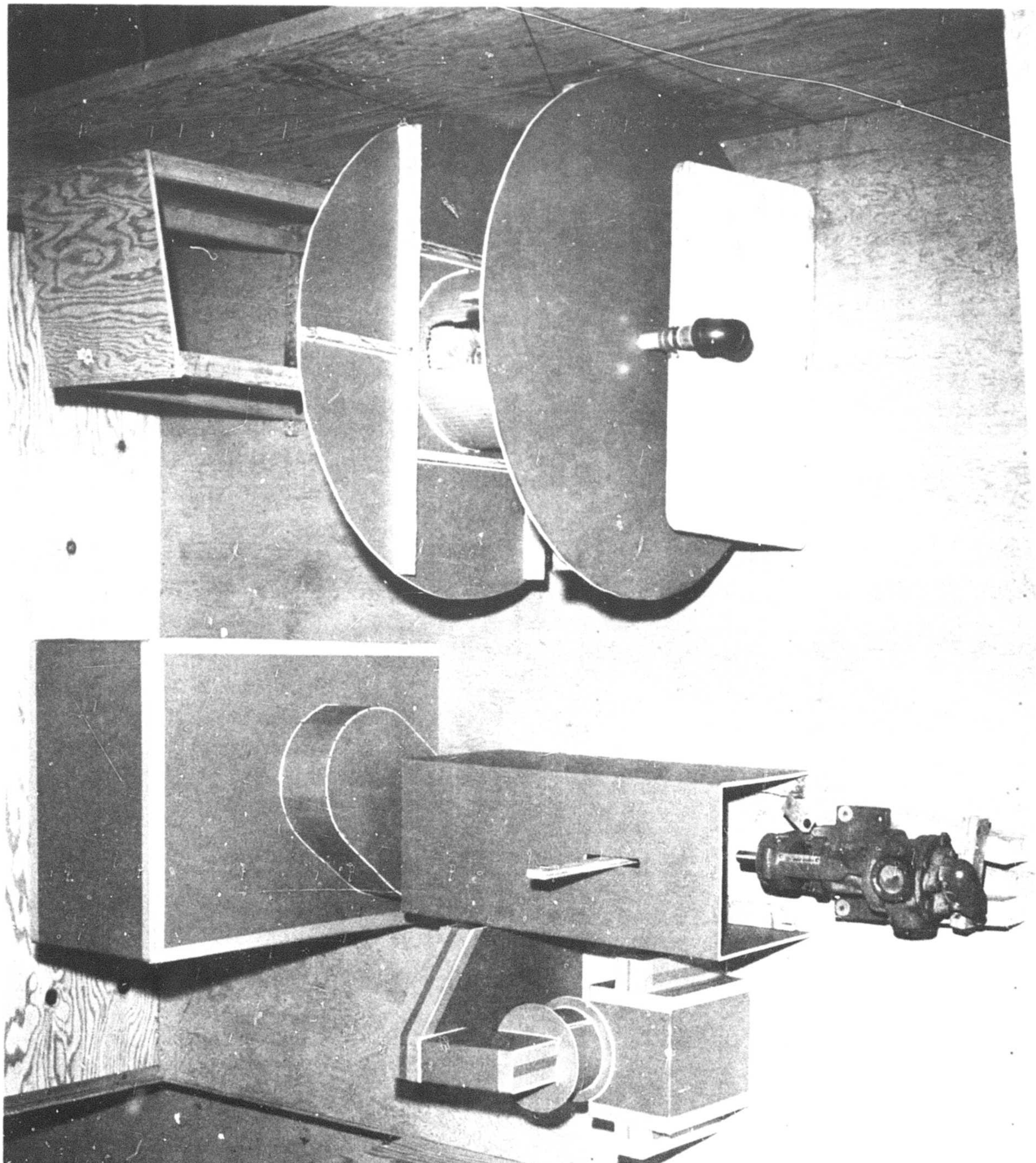
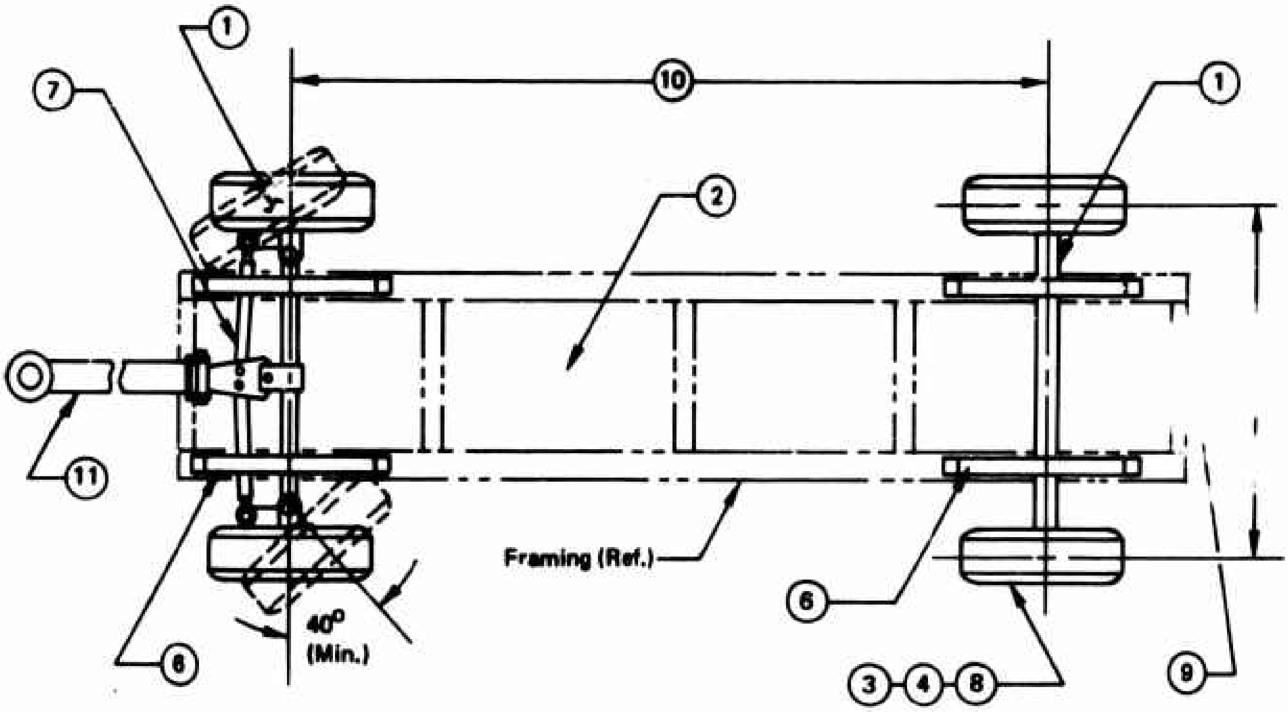


Figure 76: SPACE MOCKUP – LOW RATE EQUIPMENT

Table 29 : ***TRAILER CHASSIS, 4-WHEEL***

Requirements	Capabilities	Remarks
1. Must have payload capacity to accommodate pallet-mounted liquid dispensing system and a supply of surfacing materials. Maximum total payload is approximately 13,000 lb.	1. A trailer of appropriate size and payload capability will be provided. Construction will be per MIL-M-008090E, Type III, Group C.	1. Supplier & Supplier Part Number: Subcontracted
2. Must have sufficient area to provide storage space for fiberglass dispensing yoke, hand rollers, waste containers and other associated equipment. Approx. required bed size is 8 ft x 20 ft.	2. Trailer chassis will accommodate bed of sufficient size.	2. No suitable military trailers were known to be available conforming to the applicable specifications as well as surfacing system requirements. Therefore, the trailer was constructed by a subcontractor.
3. Must be capable of being towed by standard military vehicles at both cross-country and at normal convoy speeds.	3. Will meet requirement. See Figure 77	
4. Trailer assembly (less surfacing materials) must be air-transportable by C-130 or larger aircraft.	4. Will meet requirement.	
5. The trailer shall be designed and constructed in accordance with MIL-M-008090E and shall withstand flight and taxiing acceleration forces as specified in MIL-A-8421	5. Will meet requirement.	



1.	Running Gear	Per MIL-M-008090E Type III Group C
2.	Payload Capacity	13,000 Lb
3.	Tires	10.00 x 20, Nondirectional Cross Country Tread
4.	Wheels	20 x 7.5 Military, Per Ord. No. D7389618
5.	Track	80 Inches
6.	Suspension	Leaf Spring with Shock Absorbers
7.	Steering	Front Axle, Ackerman Type
8.	Brakes	Air Over Hydraulic with Mechanical Parking Brakes (All Wheels)
9.	Pintle Hook	Per MS 51118
10.	Wheelbase	200 Inches, Approx.
11.	Towbar	Hinged Type with Lunette Eye and Latch
12.	Towing Speed	60 MPH Maximum
13.	Operating Surface	Highway, Graded Gravel and Cross Country
14.	Ground Clearance	14 Inches, Minimum
15.	Electrical	12-Volt Complete System per MIL-M-008090E

Figure 77 : GENERAL ARRANGEMENT AND DESIGN DATA TRAILER CHASSIS – LOW RATE SYSTEM

3.4.4.3.2 Power Plant

The engine selected for the low rate equipment system was based on a maximum system continuous power requirement of 3.6 HP. As was the case with the engine selected for the high rate equipment system it was a commercial engine with an equivalent rating comparable to MIL-E-11275. As previously discussed in Section 3.4.2.3.3 the commercial engine was selected as no comparable military specification engine was currently in production. Data for the selected engine is presented in Table 30.

3.4.4.3.3 Liquid Pumps

The low rate surfacing system was required to have the capability to apply 2 lb/sq ft surfacing at a rate of 2,000 square feet per hour. In order to support this rate, a coverage rate of approximately 163 square feet per minute during the actual spraying cycle is required assuming 0.4 lb/sq ft fiberglass. This coverage rate was based on covering fiberglass strips 50 feet x 6.5 feet in two minutes of actual spraying time, as described in Section 3.3 (Operational Usage Study). A minimum rate of 42 lb/min of liquid was selected, based on maintaining minimum consistent resin pump output delivery while providing a reasonable minimum operational rate. Therefore, assuming a deposited material comprised of 40% fiberglass and 60% liquids (by weight), the total liquid system dispensing rates are as follows:

<u>MAXIMUM:</u> $163 \text{ sq ft} \times \dfrac{.6 \text{ lbs liquid}}{\text{sq ft}} = 97.8 \dfrac{\text{lbs}}{\text{min}}$ (total liquid)

<u>MINIMUM:</u> $42 \dfrac{\text{lbs}}{\text{min}}$ (total liquid)

Catalyst and Promoter Pump: As previously discussed, the liquid surfacing materials must be capable of curing at temperatures from + 40°F to +95°F at 100% relative humidity within one hour. To provide an acceptable gel time of approximately 10 to 30 minutes, the active catalyst flow rate must be variable from approximately .25 parts per 100 parts of resin by weight (PHR) to 1.5 PHR and the promoter flow rate must be variable from approximately .25 PHR to 1.5 PHR. Maximum catalyst flow rate occurs with a minimum amount of promoter entered into the liquid composition and minimum catalyst flow rate occurs with a maximum amount of promoter entered into the liquid composition. Maximum-minimum promoter flow rate occurs with a minimum-maximum amount of catalyst entered into the liquid composition.

Since the catalyst is 40% active, the actual liquid flow rates are .625 PHR to 3.75 PHR. Therefore, the required catalyst dispensing rates are:

<u>MAXIMUM:</u> $97.8 \dfrac{\text{lbs liquid}}{\text{min}} \times \dfrac{3.75 \text{ lbs catalyst}}{104.0 \text{ lbs liquid*}} = 3.53 \dfrac{\text{lbs catalyst}}{\text{min}}$

*liquid composition is 100 parts resin + 3.75 parts catalyst + 0.25 parts promoter

Table 30 : POWER PLANT

Requirements	Capabilities	Remarks
1. Power unit for operating the equipment shall include an electric starting system and shall have a continuous brake horsepower rating of not less than the equipment's maximum input power requirements. Horsepower requirements are as follows: Resin Pump 2.0 H.P. Metering Pump (Dual Head) 0.5 H.P. Total Input for Pumps 2.5 H.P. Assuming 80% drive efficiency, total H.P. Requirement for pumps is: $\frac{2.5}{0.80} = 3.1$ H.P. Power for lights 0.5 H.P. Total continuous H.P. =3.6	1. An electric starter is furnished with the power unit. Power output is 7.4 continuous horsepower at 3300 RPM. (This is 80% of peak output as recommended for continuous operation). A 30-amp Alternator is provided.	1. Supplier & Supplier Part Number: Wisconsin Motor Corporation Model AENLD with 8:1 Reduction Unit, electric starter, 30 amp alternator, and speed regulator.
2. Reduction assembly required to match gear train requirements for pump drive.	2. A reduction assembly was provided with reduction of 6 to 1 as part of power unit.	
3. All engines shall conform to MIL-E-11275, MIL-E-11276, or MIL-E-62014; however should excessive schedule delay result from this requirement, then with approval of Officer in Charge of Contracts a commercial engine of equivalent rating may be substituted.	3. Power plant engine has equivalent rating of comparable MIL-E-11275 engine.	

3.4.4.3.3 Liquid Pumps (Cont)

MINIMUM: $42 \frac{\text{lbs liquid}}{\text{min}} \times \frac{.625 \text{ lbs catalyst}}{102.125 \text{ lbs liquid**}} = .257 \frac{\text{lbs catalyst}}{\text{min}}$

(**liquid composition is 100 parts resin + 0.625 parts catalyst + 1.5 parts promoter)

Based on the promoter quantity requirements the required promoter dispensing rates are:

MAXIMUM: $97.8 \frac{\text{lbs liquid}}{\text{min}} \times \frac{1.5 \text{ lbs promoter}}{102.125 \text{ lbs liquid**}} = 1.44 \frac{\text{lbs promoter}}{\text{min}}$

MINIMUM: $42 \frac{\text{lbs liquid}}{\text{min}} \times \frac{.25 \text{ lbs promoter}}{104.0 \text{ lbs liquid*}} = .101 \frac{\text{lbs promoter}}{\text{min}}$

Based on the calculated catalyst and promoter dispensing rates and the requirement for variable flow, a duplex metering type pump was selected for this application.

Table 31 lists the requirements and capabilities of the selected pump. This pump has the capability of pumping both catalyst and promoter through separate sides of the pump while requiring only a single drive train. It was selected over providing two separate pumps (one each for the catalyst and promoter) because of less space required and the elimination of a pump drive system.

Resin Pump: The maximum resin amount required results when the least amounts of catalyst and promoter required to effect cure are entered into the liquid composition. Minimum resin amount required results when the greatest amounts of catalyst and promoter required to effect cure are entered into the liquid composition. Therefore, required resin dispensing rates are:

MAXIMUM: $97.8 \frac{\text{lbs liquid}}{\text{min}} \times \frac{100 \text{ lbs resin}}{100.875 \text{ lbs liquid*}} = 97 \frac{\text{lbs resin}}{\text{min}}$

(*liquid composition is 100 parts resin + 0.625 parts catalyst + 0.25 parts promoter)

MINIMUM: $42 \frac{\text{lbs liquid}}{\text{min}} \times \frac{100 \text{ lbs resin}}{105.25 \text{ lbs liquid**}} = 39.9 \frac{\text{lbs resin}}{\text{min}}$

(**liquid composition is 100 parts resin + 3.75 parts catalyst + 1.5 parts promoter)

The positive displacement pump selected based on the calculated dispensing rates is described in Table 32. This type of pump (used in the On-Fast system) has exhibited consistently satisfactory performance.

Table 31 : *METERING PUMP, CATALYST AND PROMOTER*

Requirements	Capabilities	Remarks
1. (a) Deliver 3.6 pounds per minute of Noury S0046 (Green) catalyst emulsion and deliver any desired lesser amount down to 0.6 pounds per minute without changing pump speed. Also deliver catalyst at rates proportionately lower when the pump speed is reduced to 41% of the maximum. Minimum catalyst delivery rate is 0.2 pounds per minute. (b) Deliver dimethyl aniline at 1.5 pounds per minute or any lesser amount down to 0.25 pounds per minute without changing speed. Also deliver promoter at rates proportionately lower when the pump speed is reduced to 41% of maximum. Minimum promoter delivery rate is 0.1 pounds per minute.	1. Pump capacity at 200 psi and 144 strokes per minute is 31.4 GPH (5.1 Pounds/Min.) Flow is approximately proportional to speed at lower speeds. On this type of pump, catalyst and promoter output can be independently controlled and either or both may be set to zero if desired.	1. Supplier & Supplier Part Number : Milton Roy Company Model FR250 Controlled Volume Pump.
2. Inject catalyst and promoter into the resin at up to 200 psi.		2. In order to pump the high viscosity catalyst, the catalyst side of the pump was modified to reduce the viscous drag of the fluid. This type of pump with similar modifications has exhibited satisfactory performance in the ON-FAST 10-Manual Spray Units program. For improved self-cleaning, ball check valves were used in the modified pump inlets.

Table 32: RESIN PUMP

Requirements	Capabilities	Remarks
1. Deliver 97 pounds per minute maximum to 40 pounds per minute minimum by changing the pump speed. Resin viscosity range to be accommodated is 80 to 1000 centipoises (CPS).	1. The pump is rated at 23 GPM (approx. 210 pounds per minute).for fluids having a viscosity of 7,500 SSU (1,830 CPS). Flow is approximately proportional to RPM.	1. Supplier & Supplier Part Number: Viking Pump Division of Houdaille Industries, Inc. Model HL 195
2. Deliver resin at pressures as high as 250 psi.	2. The pump is rated for 250 psi when pumping fluids having a viscosity greater than 100 SSU. (23 CPS)	2. This type of pump has been used in the On-Fast program and has exhibited consistent, reliable service.

3.4.4.3.4 Fiberglass Dispensing Yoke

A yoke type adapter was required for unrolling the fiberglass matting during surfacing operations. Accordingly the fiberglass dispensing yoke shown in Figure 78 was designed and fabricated. This yoke can accommodate fiberglass matting rolls with diameters up to approximately 18 inches. By adjusting the telescoping ends, fiberglass widths from 5 feet to 6.5 feet may be used. The yoke is designed to be used manually, however, the lunette eye provided allows it to be towed by standard military vehicles.

3.4.4.3.5 Fiberglass Rolling Equipment

The surfacing materials verification portion of the program indicated the necessity for rolling the surfacing materials if adequate strengths were to be obtained. Since the low rate equipment system was designed to provide surfacing capability not only for level but also rough irregular sloped and uneven surfaces the roller shown in Figure 79 was designed and fabricated. Weighing approximately 14 pounds, it was designed for one man operation on these types of surfaces. A telescoping handle was provided. In the extended position, 6.5 feet wide fiberglass may be rolled without the necessity of disturbing the uncured surfacing materials. The portable solvent container shown in Figure 80 was provided for cleaning the roller both during and at the completion of surfacing operations.

3.4.4.4 Fluid Dispensing Systems

The fluid system for the low rate equipment is basically similar to that of the high rate system. As was the case with the high rate system, design for the low rate system closely resembles that of previous On-Fast equipment. Figure 81 shows schematically the major elements of the resin, catalyst, promoter, and solvent systems.

In the resin system, resin is drawn from one of the two resin containers through a 2 inch flexible suction hose. During surfacing operations, the resin quantity remaining in these containers is monitored by the equipment operator. The 2 inch hose is equipped with a dry "quick connect-disconnect" fitting which allows the equipment operator to manually transfer the hose from one resin container to the other with minimum liquid spillage. From the discharge side of the pump a 1-1/2 inch line runs to a "tee" connection where resin flow is split into two 1 inch lines. These 1 inch lines continue to the hose reel where each is connected to a 50 foot 1-1/4 inch flexible hose. Two assemblies are provided for resin dispensing. One is a hand-held spraybar, the other a spray gun. The spraybar has a capacity of approximately 100 pounds of liquids per minute and is used when applying surfacing materials over large, relatively even terrain. The spray gun has a capacity of approximately 55 pounds of liquids per minute and is used when applying surfacing materials over smaller areas of rough uneven terrain.

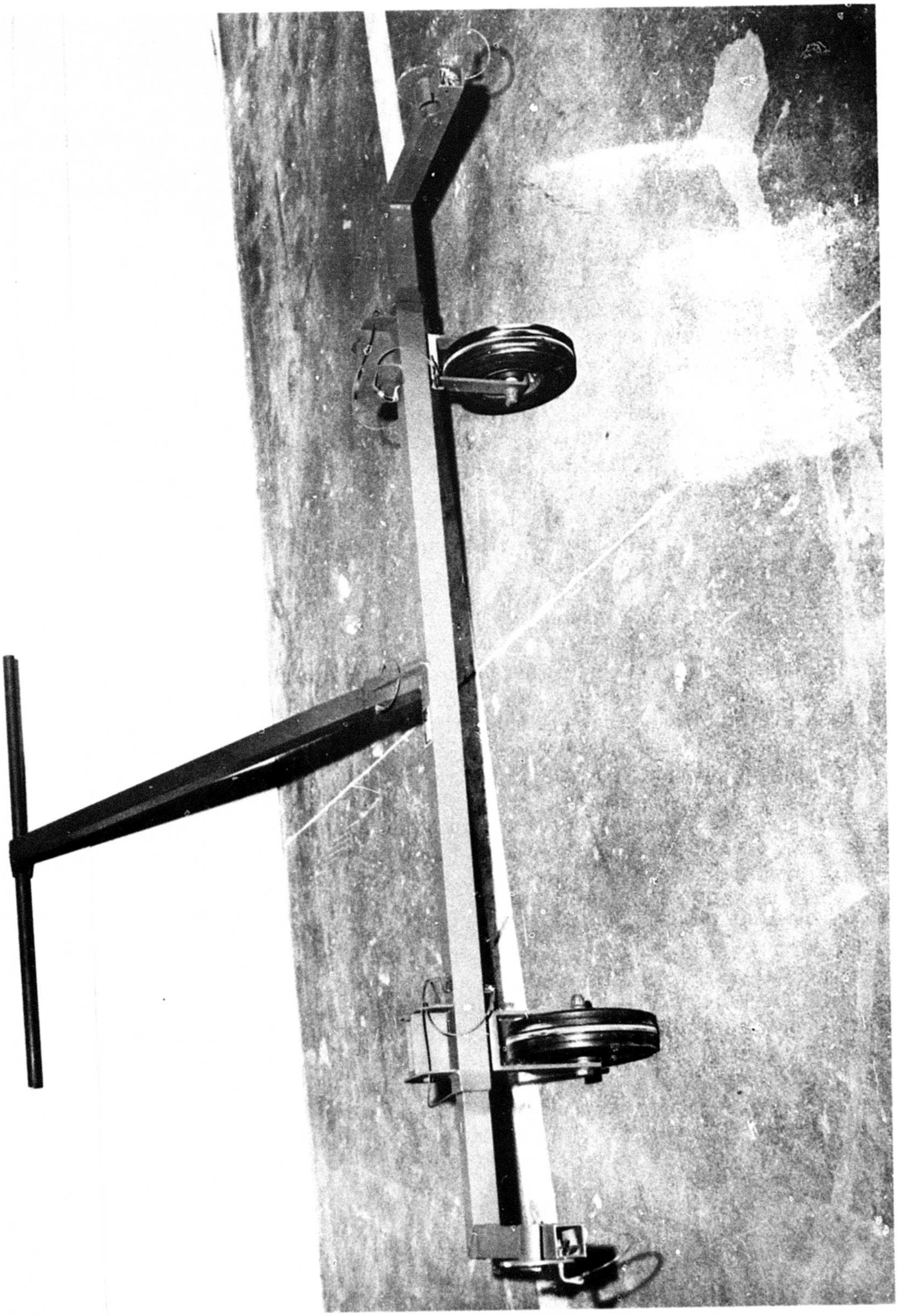


Figure 78 : GLASS DISPENSING YOKE

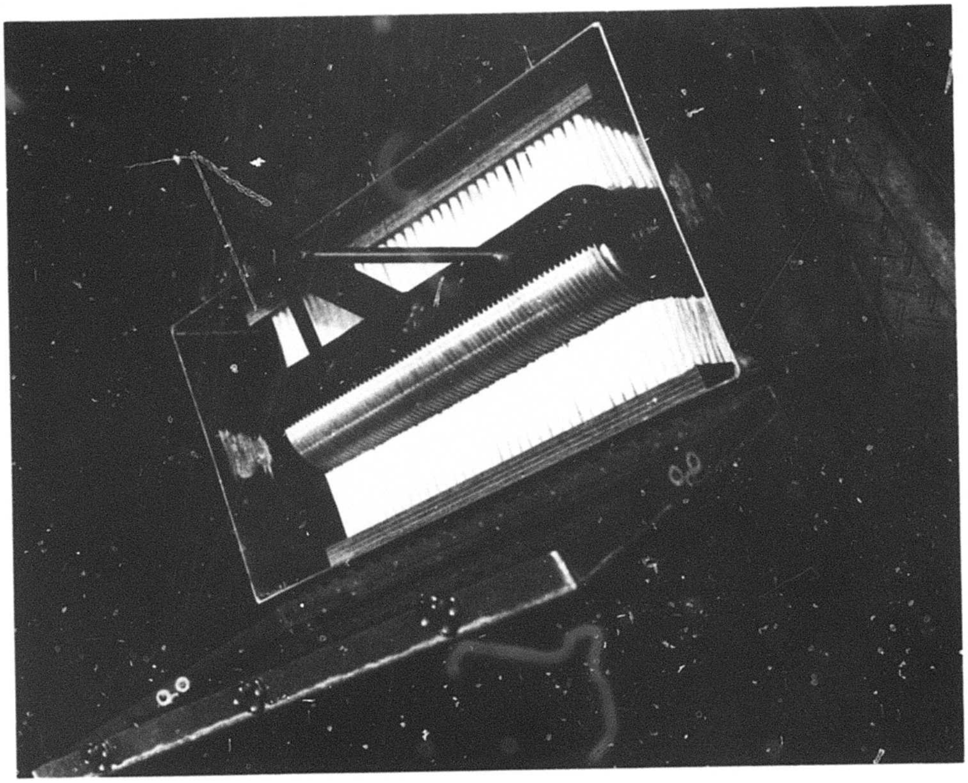


Figure 80: PORTABLE SOLVENT TANK

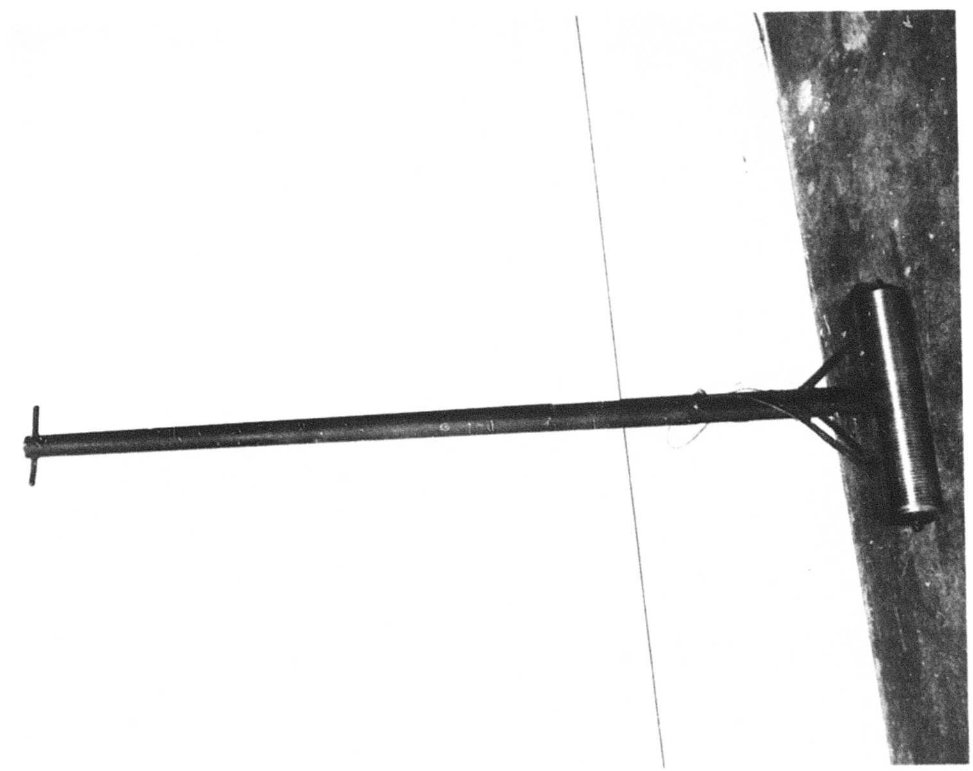
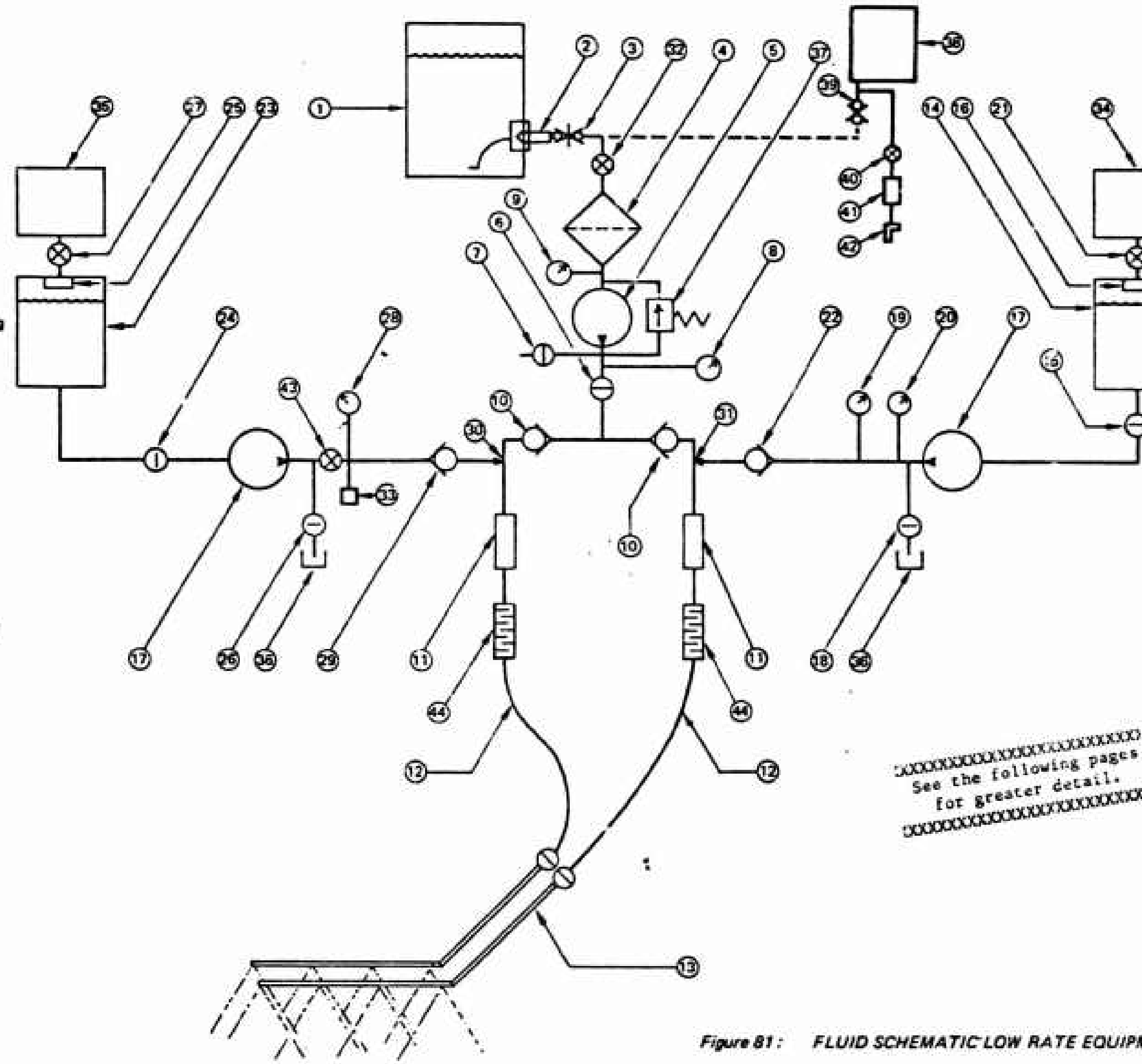


Figure 79: GLASS ROLLER

No.	Name	Qty	Description
1.	Resin Container, with Connector	1	Approx. 380 Gallon –
2.	Piercer, Resin Container	2	
3.	Disconnect, Resin	1	Integral Shut-off Type
4.	Strainer, Resin	1	20 mesh
5.	Pump Resin, with Integral Relief Valve	1	Viking Model HL124
6.	Shut-off Valve, Resin	1	
7.	Bleed Valve Resin	1	
8.	Pressure Gage, Resin	1	0 – 500 psi
9.	Temperature Gage, Resin	1	-75 to +225 degrees F
10.	Check Valve, Resin	2	
11.	Blender, Liquid (Plenum Chamber)	2	
12.	Hose Assembly	2	1" I.D. x Approx 50 Ft. Long
13.	Spraybar Assembly	1	With On-Off Valves
14.	Reservoir, Catalyst	1	75-Gallon
15.	Catalyst Supply Valve	1	
16.	Screen, Catalyst	1	(Part of Catalyst Reservoir)
17.	Pump, Metering, Catalyst and Promoter	1	Milton Roy Model FR 251
18.	Bleed Valve, Catalyst	1	
19.	Temperature Gage, Catalyst	1	-75 to +225 Degrees F.
20.	Pressure, Gage Catalyst	1	0 – 500 psi
21.	Catalyst Fill Valve	1	
22.	Check Valve, Catalyst	1	
23.	Reservoir, Promoter	1	41-Gallons
24.	Promoter Supply Valve	1	
25.	Screen, Promoter	1	(Part of Promoter Reservoir)
26.	Bleed Valve, Promoter	1	
27.	Promoter Fill Valve	1	
28.	Pressure Gage, Promoter	1	0 – 500 psi
29.	Check Valve, Promoter	1	
30.	Injector, Promoter	1	
31.	Injector, Catalyst	1	
32.	Disconnect, Resin	1	
33.	Pressure Actuated Relay	1	(Electric Clutch Control)
34.	Catalyst Drum	1	55-Gallon
35.	Promoter Drum	1	30-Gallon
36.	Plastic Bucket	2	
37.	Relief Valve	1	(Part of Pump)
38.	Solvent Drum	1	55-Gallon
39.	Adapter	1	
40.	Shut-off Valve-Solvent	1	
41.	Solvent Pump	1	Electric Driven (12-Volt)
42.	Solvent Spray Gun	1	
43.	Pressure Control Valve	1	Maintain 50 psi Back Press.
44.	Static Blender		



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See the following pages
for greater detail.
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Figure 81 : FLUID SCHEMATIC LOW RATE EQUIPMENT

3.4.4.4 Fluid Dispensing Systems (Cont)

The catalyst and promoter systems are similar with the exception of line size. The catalyst is drawn from the on-board liquid container through a 1-1/2 inch flexible suction hose to one side of the duplex metering pump. On the discharge side of the pump catalyst is delivered through a 1/2 inch line to the catalyst injection point on one of the 1 inch resin lines. The promoter is drawn from its respective on-board container through a 1/2 inch flexible hose to the other side of the duplex metering pump where it is delivered through 3/8 flexible hose to the promoter injection point on the other 1 inch resin line.

When cleaning and flushing the low-rate fluid system, it is not necessary to remove the resin containers as it is in the high rate system. All solvent required is available from the on-board 55 gallon solvent drum. A manifold arrangement connected to the solvent drum allows both the 2 inch resin suction line and the suction line for the portable solvent spraygun pump unit to be connected to a common solvent source. Cleaning of the fluid system is accomplished similar to that of the high rate fluid system. Catalyst and promoter systems are drained of any reactive liquids and the hoppers filled with enough solvent to allow thorough system cleaning. The portable solvent spraygun may be used to fill the hoppers with solvent. Solvent is then pumped through the liquid systems by means of their respective pumps. If desired, the catalyst and promoter systems may be flushed independent of the resin system by disengaging the resin pump by means of the manually operated clutch.

3.4.4.4.1 Catalyst System Design

Similar to the high rate fluid system, the effects of maximum catalyst viscosity on system design were critical. In order to determine these effects, a test setup that simulated the planned catalyst system was devised. This test setup utilized a metering pump that was available from previous programs. This pump was the same type as the one planned for procurement except that it had a slightly larger plunger diameter, however, it was capable of duplicating the required catalyst output range. Suction line plumbing simulating the planned configuration was utilized and ball type check valves instead of plate type check valves were installed in the pump inlet port for improved self-cleaning. Catalyst at 40°F was pumped at the maximum required rate and both material output and pressure drops determined. These values were used for designing the catalyst system.

3.4.4.4.2 Nozzle Selection

Concurrent with the nozzle evaluation tests previously discussed in Section 3.4.2.4.2, various nozzles were evaluated for suitability with the low rate fluid dispensing system. As before, these tests included measurement of nozzle output, fan angle, pressure, and evenness of resin distribution. Nozzle tests for the low rate system were also accomplished over a range of resin viscosities from approximately 80 cps to 1600 cps. Based on these tests, a Spraying Systems 9520 nozzle was found acceptable for viscosities ranging from 80 to approximately 1000 cps and a Spraying Systems 11015 acceptable for the high viscosity (1600 cps) resin for use with the hand-held spraybar. With the hand-held spraygun, Spraying Systems 9520 or 9530 nozzle was found satisfactory for normal operations. However, using the hand-held spraygun for dispensing the 1600 cps resin a Spraying Systems 11020 nozzle (modified by increasing bore size) is required.

3.4.4.4.3 Fluid Blending

The tests previously described in Section 3.4.2.4.3 were also used as the basis for selecting the method of resin-catalyst and resin-promoter blending and injection for the low rate fluid dispensing system. The satisfactory performance of the 'kenics", in line mixing tube as determined by gel time samples taken, led to its selection for the low rate system. These tests also indicated that single injection in conjunction with the mixing plenum chamber and blender was the most satisfactory combination to ensure adequate blending for the low rate system.

3.4.4.4.4 Fluid System Calculations

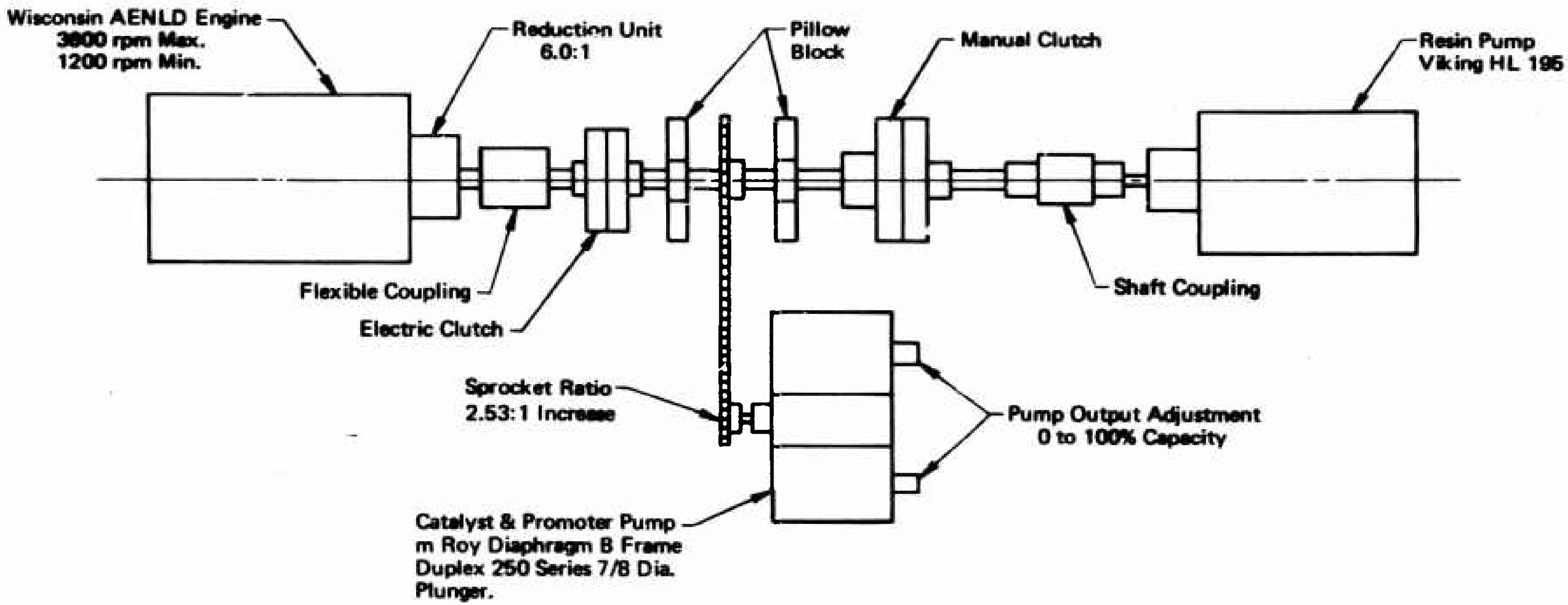
The fluid system calculations described in Section 3.4.2.4.4 and the typical examples shown were the methods used for the design of the low rate fluid system. Similar to the high rate system, components such as valves, fittings, etc., were generally assigned an equivalent length of straight pipe based on test experience and recommendations made in Reference 17. The resin and catalyst systems were designed on the basis of laminar flow due to high viscosity of these materials while elements of the promoter system were designed on the basis of turbulent flow due to the low viscosity of this material.

3.4.4.5 Methods fo Controlling the Material Dispensing Rates

The overall drive system from the engine to the liquid pumps is shown schematically in Figure 82. Detail information on the engine and pump capabilities has been previously discussed in Section 3.4.4.3.

Control of liquid dispensing rates is achieved by varying the engine rpm. Both the resin pump and metering pump are mechanically connected positive displacement pumps, therefore the outputs are approximately proportional to each other and to engine speed. The metering pump dispenses promoter and catalyst through separate chambers but utilizes a common drive. Catalyst and promoter flow rates are independently variable at any given speed through separate chambers but utilize a common drive. Catalyst and promoter flow rates are independently variable at any given speed through separate metering controls on the pump.

The fiberglass is manually unrolled before the liquid is applied. The amount of liquid applied per square foot of fiberglass is controlled by the spraybar operator. For a given liquid dispensing rate and given weight of fiberglass faster coverage results in a lower resin to glass ratio. Figure 83 is illustrative of this and presents data on spraybar operator walking speed required versus liquid output for various widths of fiberglass. This data is based on a single layer of fiberglass and a constant ratio of 0.6 pound liquids to 0.4 pound fiberglass.



Engine Speed (rpm)	Resin Pump Speed (rpm)	Resin Pump Output (gpm)	Pro. & Cat. Pump Speed (Strokes/Min.)	Pro. & Cat. Pump Output gpm @ 100%
3300	550	10.8	114	0.419
3000	500	9.7	104	0.383
2700	450	8.7	94	0.346
2400	400	7.7	83	0.305
2100	350	6.7	73	0.268
1800	300	5.7	63	0.232
1500	250	4.6	52	C.191

Figure 82: PUMP DRIVE SYSTEM, LOW RATE SURFACER

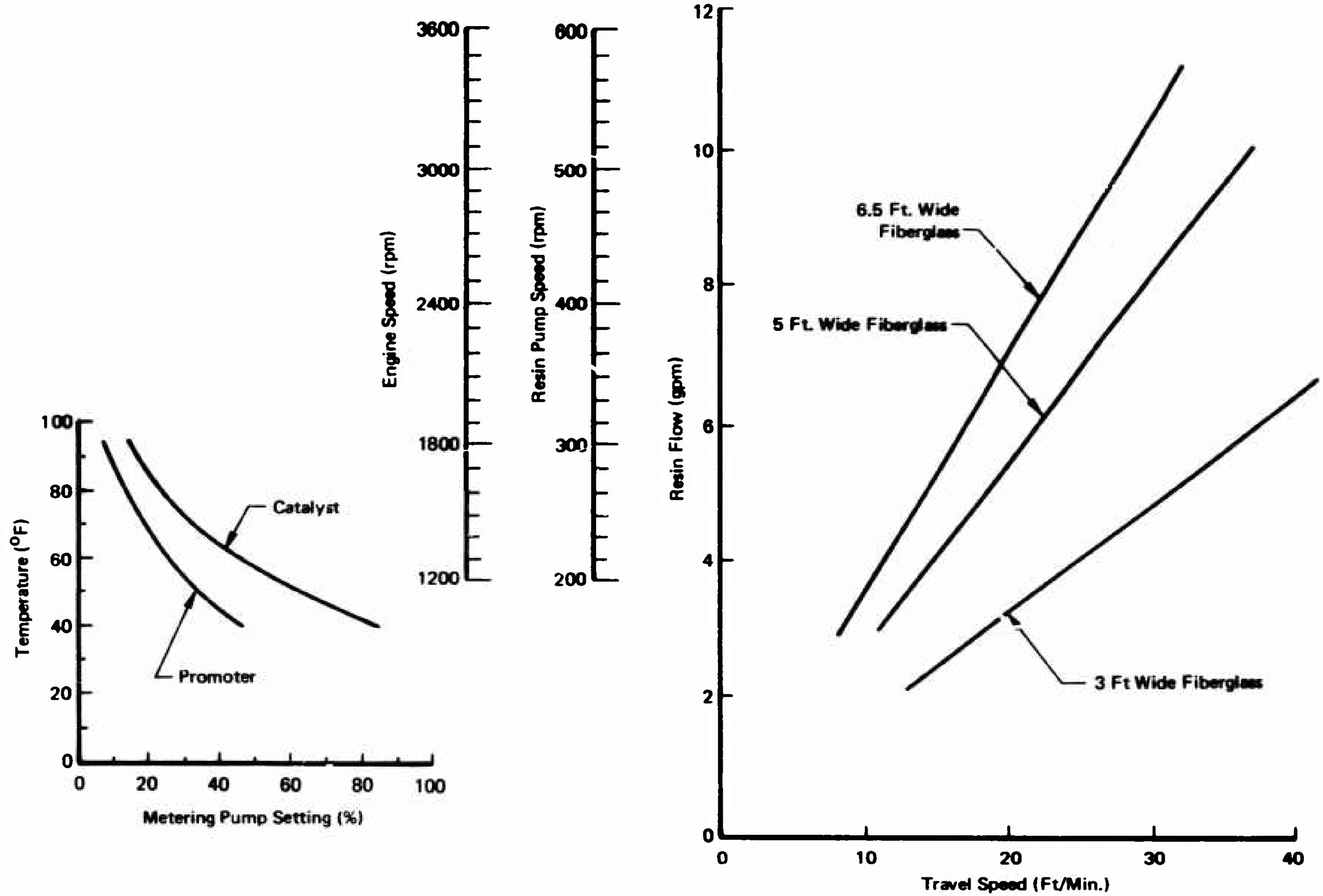


Figure 83 : ***MATERIALS DISPENSING RATE CONTROL, LOW RATE SURFACER (SC19-143 RESIN)***

3.4.4.6 Operator Controls and Instruments

The low-rate surfacer operator's controls and instruments consist of those required to control and monitor the liquid dispensing rates. Location of the operator's control panel and instruments is shown sechmatically in Figure 84. Figure 85 shows the operator's control panel. Liquid quantity indicators are similar to those provided with the high rate system. Resin quantity remaining is determined by observing the gauge marks printed on the resin container carboard lining. High and low liquid level indicators are provided in the catalyst and promoter containers. Visual observation of these markings is provided by the access openings located as also shown in Figure 84.

3.4.4.7 System Transportability

For ground transport the trailer can be towed by any conventional tow vehicle which has standard towing provisions including towbar hitch, brake air lines and connector, and electrical connector for lights. For ground transport involving appreciable distance, promoter and catalyst materials, as well as the resin containers would not be on-board. For local off-highway movement between sites, the surfacing materials and containers could remain on-board while the equipment is in transit.

For either ground or air transport, adequate storage provisions are provided for items such as the fiberglass dispensing yoke, glass rollers, portable solvent tank. manuals and records, and the portable solvent spraygun pump unit. Storage compartments are located as shown in Figure 84.

3.4.4.8 Calculations for Stability

Stability of the low-rate surfacer while of concern is inherently good, even on a 20% side slope since it is basically symmetrically loaded. This is in contrast to the high rate surfacer where eccentric loads are introduced by the boom and spraybar glass support structure during surfacing operations to the side. On a 20% slope with a single, full resin container on the low side of the trailer, the center of gravity of the resin container projected vertically downward falls inside the lower wheels ground contact line. Taking into account the additional loads, the center of gravity of the composite loads results in a pronounced stabilizing condition.

3.4.4.9 Trade-Offs

As noted for the high rate system in Section 3.4.2.9, basic system concepts and approaches were established at the beginning of the program. The trade-offs listed below are applicable to both systems and were selected for the reasons previously discussed.

- Large capacity refill hoppers for on-board containment of promoter and catalyst selected over standard drum or small manifolded containers.
- Liquid level gauge marking selected over float type indicators, weighing scales, pressure gauge system or transparent tubes for determining the amount of liquids remaining in containers.
- Portable spraygun and pump unit selected over hand-wipe for solvent cleaning of deck and equipment.

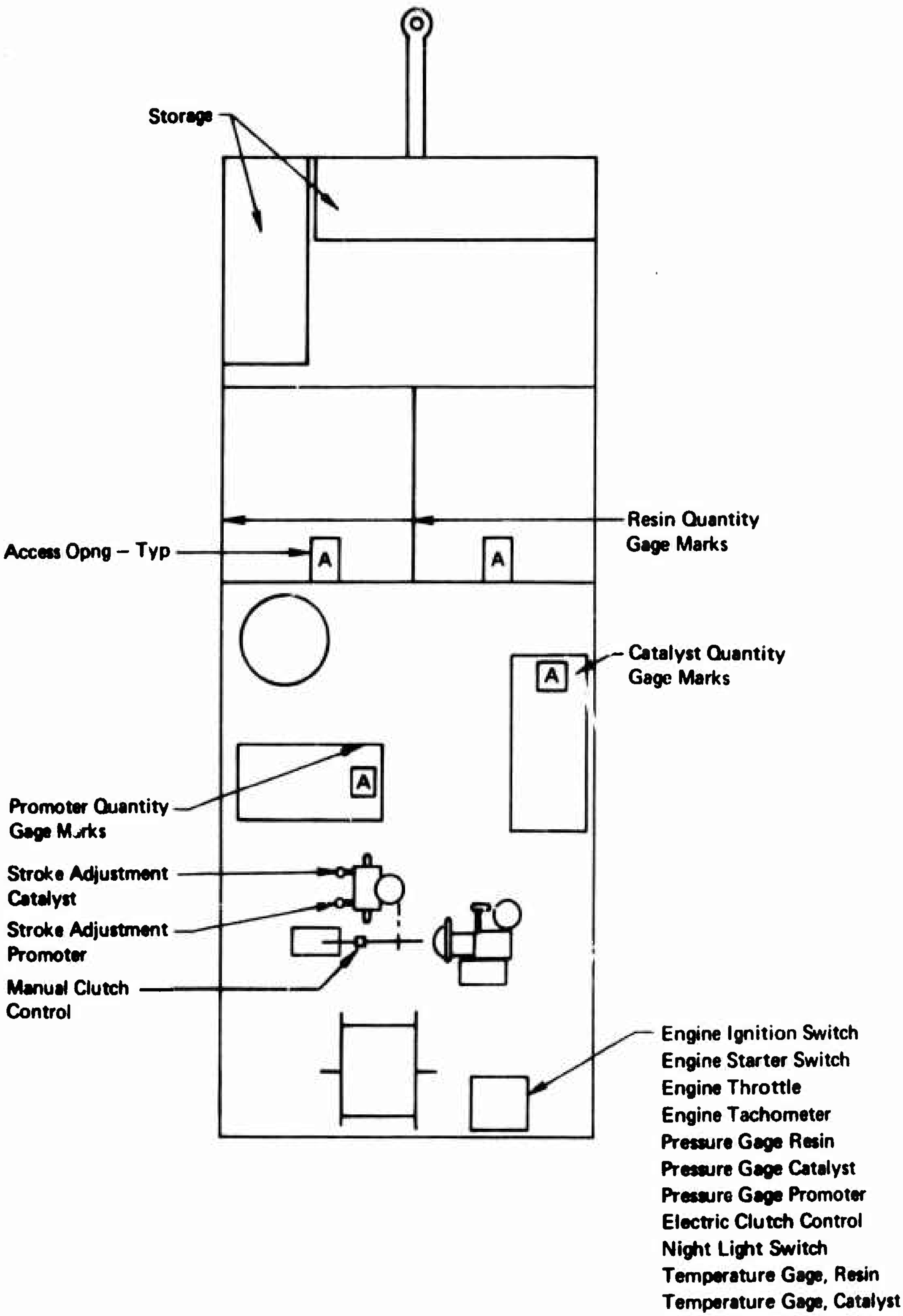


Figure 84: OPERATOR CONTROLS – LOW RATE SURFACER

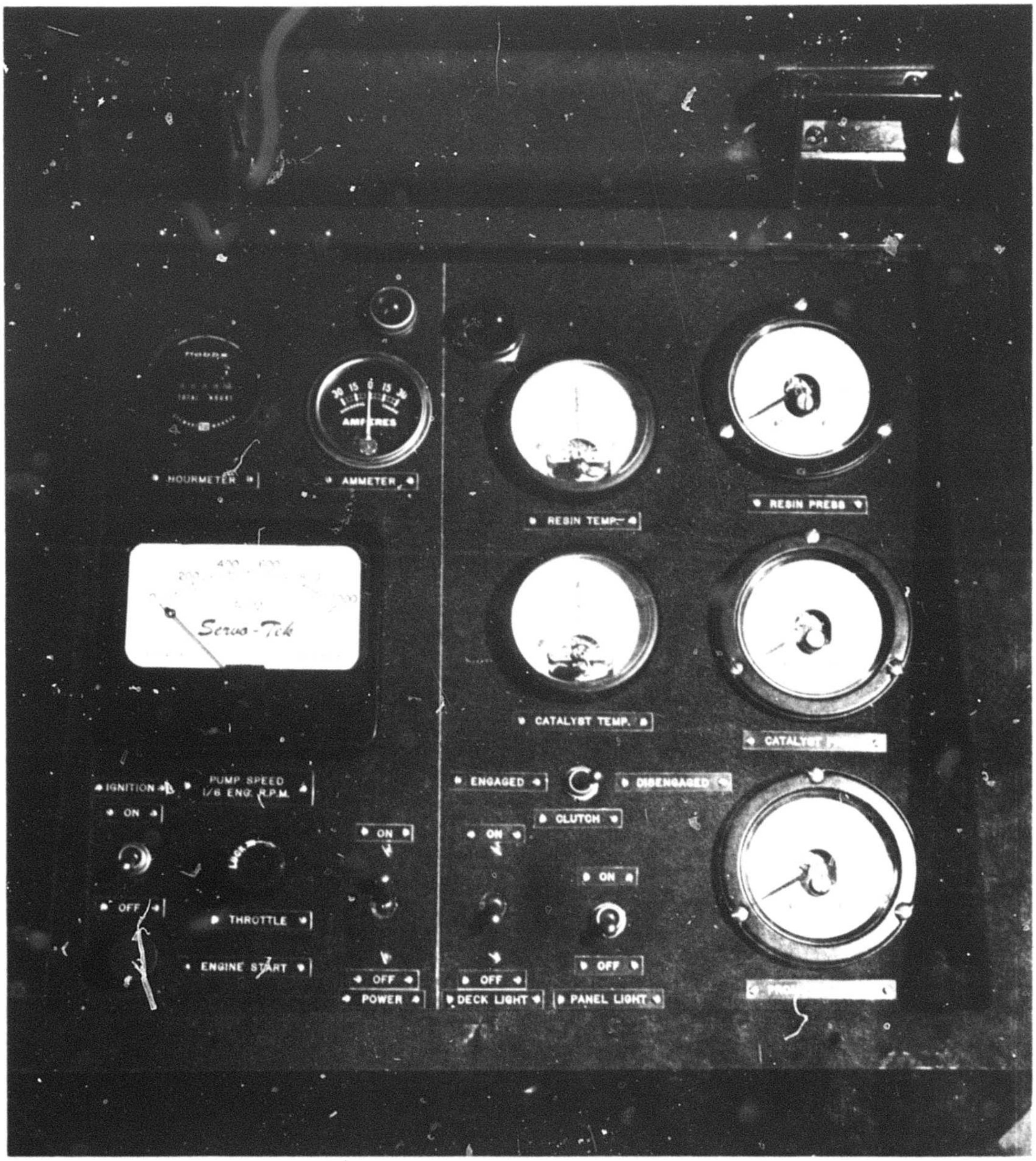


Figure 85 : CONTROL PANEL LOW RATE EQUIPMENT

3.4.4.9 Trade-Offs (Cont)

- o Portable solvent tank with brushes provided for cleaning glass rollers rather than cleaning with solvent spraygun or utilizing throw-away polyethylene sleeves.

Trade-offs considered unique to the low rate system are discussed below:

Fabrication of a special trailer chassis was selected over use of military inventory trailers for the materials containers and dispensing equipment platform. This approach was selected on the basis of weight and space requirements of the materials and dispensing equipment. No suitable military trailers were found that met these requirements.

A separate removable equipment pallet was selected for the dispensing equipment platform rather than mounting all equipment on a single base structure. The removable equipment pallet was selected on the basis of convenience for special operational or maintenance conditions.

3.4.4.10 System Fabrication

Fabrication of the low rate equipment system was accomplished in two concurrent phases; fabrication of the trailer chassis by a subcontractor and fabrication of the removable equipment pallet by Boeing. This pallet has four-way forklift provisions and is attached to the trailer chassis by 8 mounting bolts. Subsequent to pallet fabrication, major components such as the engine (Figure 86), hose reel, and control stand were mounted on the pallet. Upon receival of the trailer chassis (Figure 87), the removable pallet (Figure 88) was mounted on the trailer chassis.

As in the case of the high rate equipment, all liquid pumps were checked out prior to installation. Using simulated plumbing runs of the planned systems, pump settings versus output were established for the liquid delivery rates required. All pumps were found satisfactory in the dispensing ranges required. Subsequently they were mounted on the removable pallet and final assembly of the plumbing systems, drive train and electrical wiring completed (Figure 89 and 90). Concurrent with these final tasks, fabrication of other system items, such as the glass roller and portable solvent tank were completed in preparation for system testing.

3.4.5 GENERAL DESIGN CONSIDERATIONS

In addition to the specific design requirements for the high rate and low rate equipment systems previously discussed, design of both systems took into account reliability, maintainability, human factors, and safety. The equipment was designed to, and did successfully, pass the specified tests without danger to the operating personnel.

3.4.5.1 Reliability

Although the contract did not require a formal reliability program such as MIL-STD-785A or formal reliability analyses, reliability requirements were stated in practical terms. The systems shall be designed so as to successfully pass the specified tests with no failures preventing satisfactory performance and with no cause for rejection for reasons that would indicate early failure or high rejection rate.

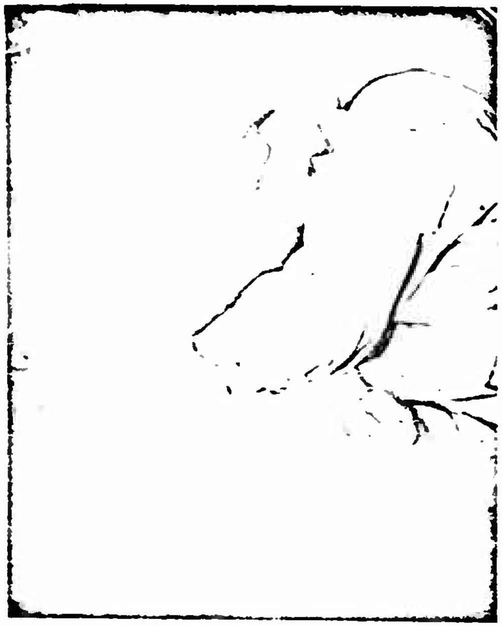


Figure 86: ENGINE INSTALLATION

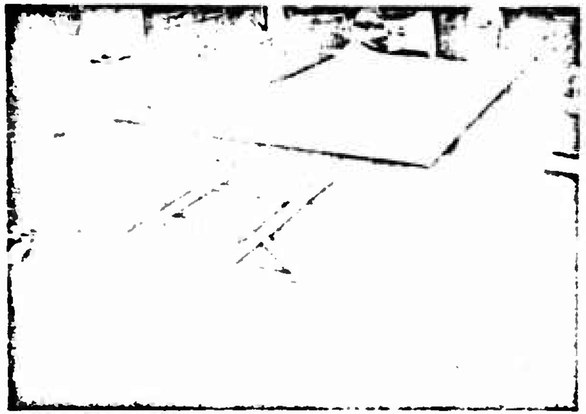


Figure 87: TRAILER CHASSIS

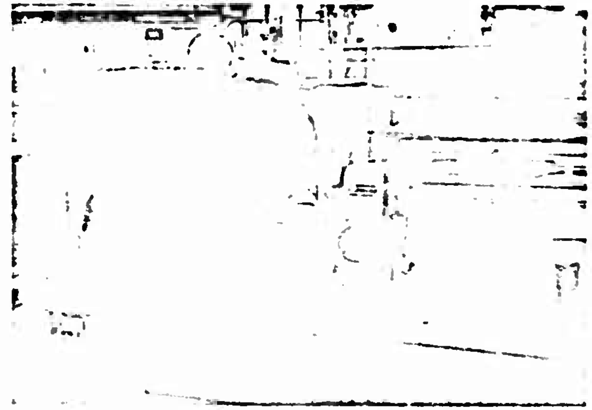


Figure 88: REMOVABLE PALLET

Figure 89: DRIVE TRAIN AND PLUMBING INSTALLATION

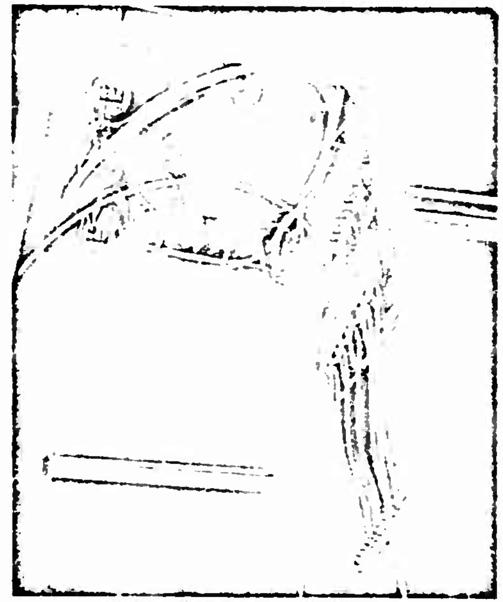


Figure 90: WIRING INSTALLATION

See the following pages for greater detail.

A

Figure 86: ENGINE INSTALLATION

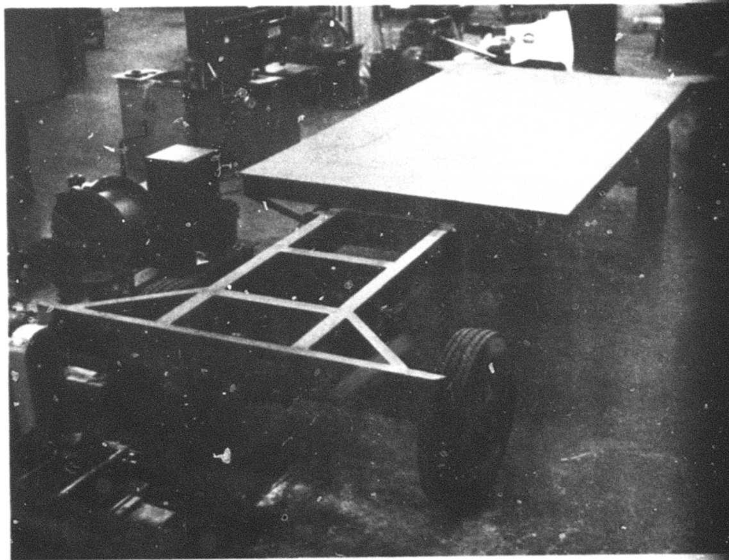


Figure 87: TRAILER CHASSIS

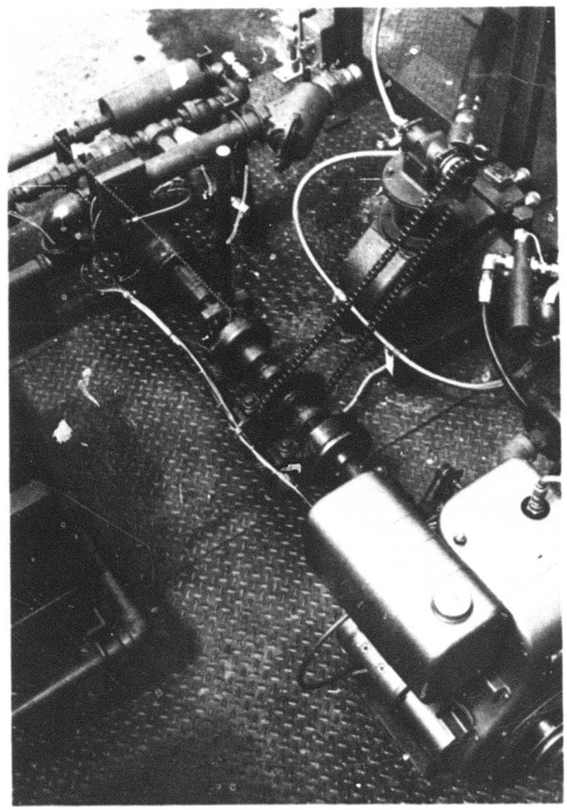
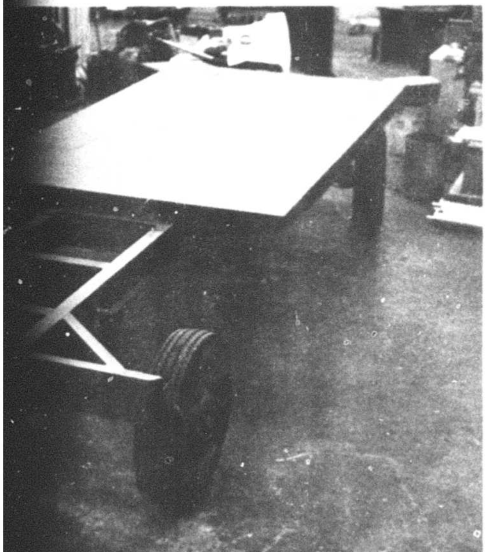


Figure 89: DRIVE TRAIN AND PLUMBING INSTALLATION



TRAILER CHASSIS

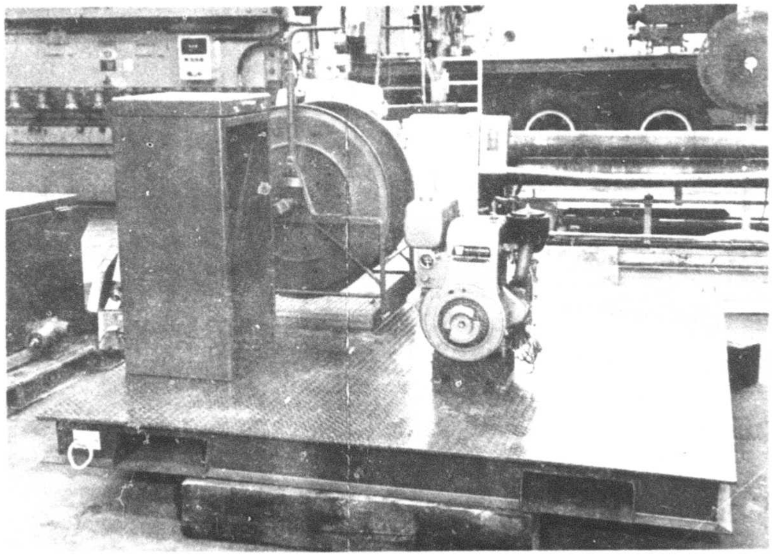
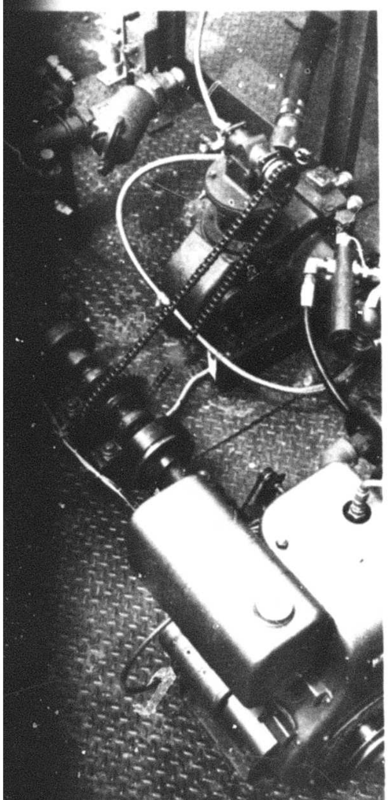


Figure 88: REMOVABLE PALLET



RIVE TRAIN AND
LUMBING INSTALLATION

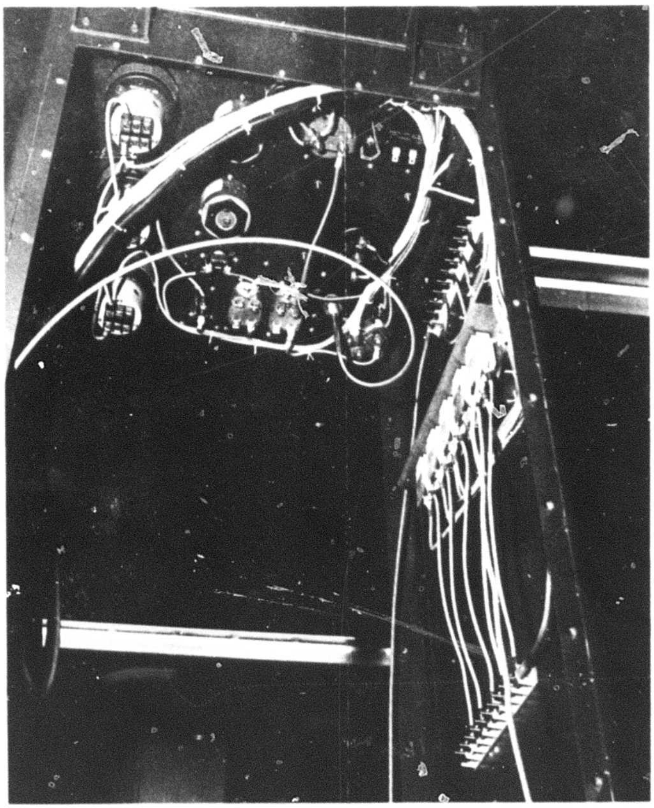


Figure 90: WIRING INSTALLATION

3.4.5.1 Reliability (Cont)

This requirement was met by careful selection of supplier's components and on the design approach used for fabricated parts. Critical components were selected which had a history of consistently reliable performance. Items included in this category were for the high rate equipment; truck, boom and turret, engine, pumps, pump drive components, valves and other plumbing components. For the low rate equipment these items included trailer, engine, pumps, pump drive components, valves and other plumbing components.

Design of fabricated parts emphasized simplicity and ruggedness as an aid in achieving overall system reliability. Preliminary system testing was performed to verify system reliability and indicate any required modifications.

3.4.5.2 Human Engineering Factors Considered

Human engineering aspects of the systems were prime considerations, since meeting the required surfacing rates with the specified number of personnel, required a very efficient operation. In order to achieve this efficiency, it was necessary that the following be incorporated into the system operation and design.

- Personnel task definition
- Ample working space
- Logical separation of work areas
- Location and grouping of controls and instruments to provide ease of control and monitoring
- Adquate lighting and communication provisions

Personnel task definition was presented in the Operational Usage Study section of this document. Figure 58 of the high rate surfacer indicates the amount of working space and separation of working areas for the equipment operator and on-board materials tender. This figure in conjunction with Figure 63 shows the location and grouping of controls and was previously discussed in Section 3.4.2.5. The full scale mockup mentioned in Section 3.4.2.2 generally demonstrated a relative arrangement of equipment that would provide for efficient operation. Ample working space, desirable separation of work areas, and convenient location of controls and instruments were exhibited. Adequate lighting for night operation for the surfacer was provided by utilizing floodlights for the work area and local lighting for the instrument panel. Floodlights were utilized on the tow tractor for night operations.

As for the high-rate surfacer, the low-rate unit also has two basic, separated work areas as shown in Figures 75 and 84. The liquid dispensing equipment with controls and instruments is in the rear section, and the materials tending in the forward section. Although the same operator performs the required tasks in each area, the work area separation tends to improve efficiency and reduce possible confusion. As was the case for the high rate unit, the full scale mockup of the low rate unit previously discussed in Section 3.4.4.2 was used to verify equipment arrangement and convenience of operators controls and instruments.

3.4.5.2 Human Engineering Factors Considered (Cont)

Adequate lighting for night operation was provided by utilizing floodlights for the work area and local lighting for the instrument panel. Also a battery powered light attached to the spraybar operator, was provided for "Remote" lighting when surfacing operations are required at extended distances from the trailer. Battery powered lights were also provided for the glass dispenser, hose tender, and glass roller operators.

3.4.5.3 Safety

Safety aspects of both equipment systems as reflected in the design approaches include large working areas relatively free of deck clutter. This situation significantly reduces the likelihood of injury to the equipment operators of both units and to the on-board materials tender in the case of the high rate surfacer. Also, guard rails are provided in critical areas and non-skid decking is utilized. An on-board fire extinguisher and an on-board source of a chemical neutralizing solution for use in case of direct exposure to the liquids, particuarly dimethyl aniline was provided.

The liquid materials container and plumbing arrangement forms a closed system to the greater practical extent, thus reducing possibility of personnel exposure to the liquids and their vapors. Also, "dry" quick connect/disconnect fittings were used for attaching the resin containers to pump feed lines, thus minimizing any drippings of liquids.

For the high rate surfacer, essentially all rotating machinery or other mechanisms relating to the pumps drive system have been placed beneath the decking, thereby reducing deck clutter, and minimizing possibility of injury. All above deck moving parts are protected by guards.

In the low rate equipment, rotating machinery related to the pumps drive system is above the deck rather than below as on the high-rate surfacer. The relatively small envelope of this system in comparison to available work space did not justify the burden of below deck installation. However, guards were provided for all moving parts which would be likely to cause injury.

3.4.5.4 Maintainability

Although the Advanced Surfacing Systems were prototype configurations, applicable maintainability requirements were followed during design. Considerable effort was given to selection of components and materials that would enable the systems to operate in an austere environment without degradation of the primary system performance requirements.

The features previously discussed in paragraphs 3.4.5.1 (Reliability), 3.4.5.2 (Human Engineering Factors Considered), 3.4.2.9 and 3.4.3.9 (Trade-Offs), and 3.4.5.3 (Safety Data), are also those that result in systems with low maintenance requirements. Specific items included in the systems design which provide good maintainability features are as follows:

1) Large, open work spaces on the deck of the high rate surfacer and low rate trailer. Deck cover plates for ready access to under deck drive system and plumbing components are provided on the high rate surfacer.

2) Corrosion resistant steel for use in lines and fittings which come in direct contact with catalyst and promoter with attendant long life and minimum need for replacement or repair of parts.

3.4.5.4 Maintainability (Cont)

3) Use of welded assemblies and tubing rather than "water pipe" plumbing, where practical, in order to provide smooth surfaces in contact with liquids with attendant improvement in flushing and cleaning.

4) Adequate instrumentation such as liquid pressure and temperature gauges to provide early indication of malfunction and necessity to repair or replace components.

5) Capability to operate each liquid subsystem (resin, catalyst and promoter) independently simplifies systems checkout.

6) Use of standard fittings and fasteners to provide assembly/disassembly with standard tools.

7) Maximum use of off-the-shelf components with demonstrated performance capability and established field repair techniques. Items in this category for both systems are engine, drive system components, pumps, valves and disconnects; with the addition of the truck, basic boom and turret for the high rate system.

In comparing the high rate equipment system with the low rate equipment system, the low rate equipment is relatively unsophisticated and should require less servicing, and preventive or corrective maintenance than the high rate system. An additional feature of the low rate system is the capability to remove only the aft section of the base structure which contains the dispensing equipment. Where shop space is at a premium, this capability would be advantageous for conducting overhaul operations.

3.5 Prototype Application Equipment Systems Tests

A series of tests was accomplished to verify that the prototype application equipment systems were capable of meeting the specified performance requirements. Both the high and low rate equipment system were subjected to testing. These tests consisted of proof pressure, long time operational testing of the fluid dispensing systems and a series of specific operational tests. Certification of equipment capability at minus 25^{O}F to plus 125^{O}F is contained in the Appendix. In addition to obtaining the weights and dimensions of the completely assembled equipment items, both equipment systems were subjected to mobility tests and air transportability checks.

3.5.1 TEST PLAN

Prior to accomplishing the specified performance tests, a test plan was prepared and submitted to NCEL for approval. This document (Reference 6) described the approaches, methods, set ups, procedures and instrumentation used to conduct these tests. In addition the document listed the tests in planned order of accomplishment. This test sequence was different than the contract schedule, however, it was chosen so that data and techniques from the untimed surfacing tests could be applied to the subsequent surfacing rate tests. Concurrent with test plan documentation, required surfacing materials were estimated and preliminary test site layouts accomplished. Upon receipt of final test plan approval surfacing materials procurement and test site acquisition was implemented.

3.5.2 TEST SITE

A test site was required to adequately perform the specified surfacing operations. The site required sufficient length and width to allow application of a minimum of 30,000 square feet of surfacing materials. Also, sufficient area for materials and equipment storage, waste surfacing materials disposal, and space for equipment maintenance and turnaround was required. In order to meet these requirements the following criteria were used in selecting a suitable test site.

1) A reasonably level area with dimensions of not less than 300 by 600 feet was required for the major portion of surfacing operations and have sufficient subgrade bearing capacity to support the test and ancillary equipment.

2) Rough and sloping terrain should be nearby for equipment capability demonstrations.

3) The selected location was to have good drainage so that no inherent swamp conditions or pooling resulting from heavy rains would occur.

4) The location was to be as near as possible to fabrication and maintenance shop areas.

5) A good access road with attendant parking area was necessary for use with passenger cars, heavy trucks, and equipment.

6) Utilities (power, water, lights, and telephone) were desirable, but portable or temporary equipment was satisfactory.

Based on the above criteria and land availability, the area shown in Figure 91 was selected. This site, adjoining Boeing's Space Center in Kent, Washington had ample room for conducting the test program, and required a minimum of contractor effort to provide and construct the test facilities.

Basic test site construction consisted of stripping and removal of existing vegetation and grading in those areas where surfacing materials would be applied. An existing earth berm and ramp were regraded to obtain the 20% sloped and hill and mound-like surfaces with 50 foot vertical radii required for surfacing operations conducted over varying terrain. A waste pit (approximately 75 cubic feet) was provided for disposal of surfacing materials during equipment checkout and cleaning operations. A layout of the test site is shown in Figure 92. Prior to actual equipment testing and surfacing operations, heavy rains destroyed the soil bearing capacity of the regraded berm and ramp area. In order to ensure timely completion of the test program it was necessary to provide additional bearing capacity for the test equipment. This was accomplished by constructing a 6-inch deep by 12-foot wide crushed rock roadway over the graded 20% side slope and vertically curved surfaces as also shown in Figure 92.

3.5.3 SURFACING MATERIALS

Concurrent with test site acquisition and site construction implementation, an estimate was made of the amount of surfacing materials required for the surfacing and cleaning operations. This initial estimate was made on the basis of using one weight and width of fiberglass reinforcement for all tests.

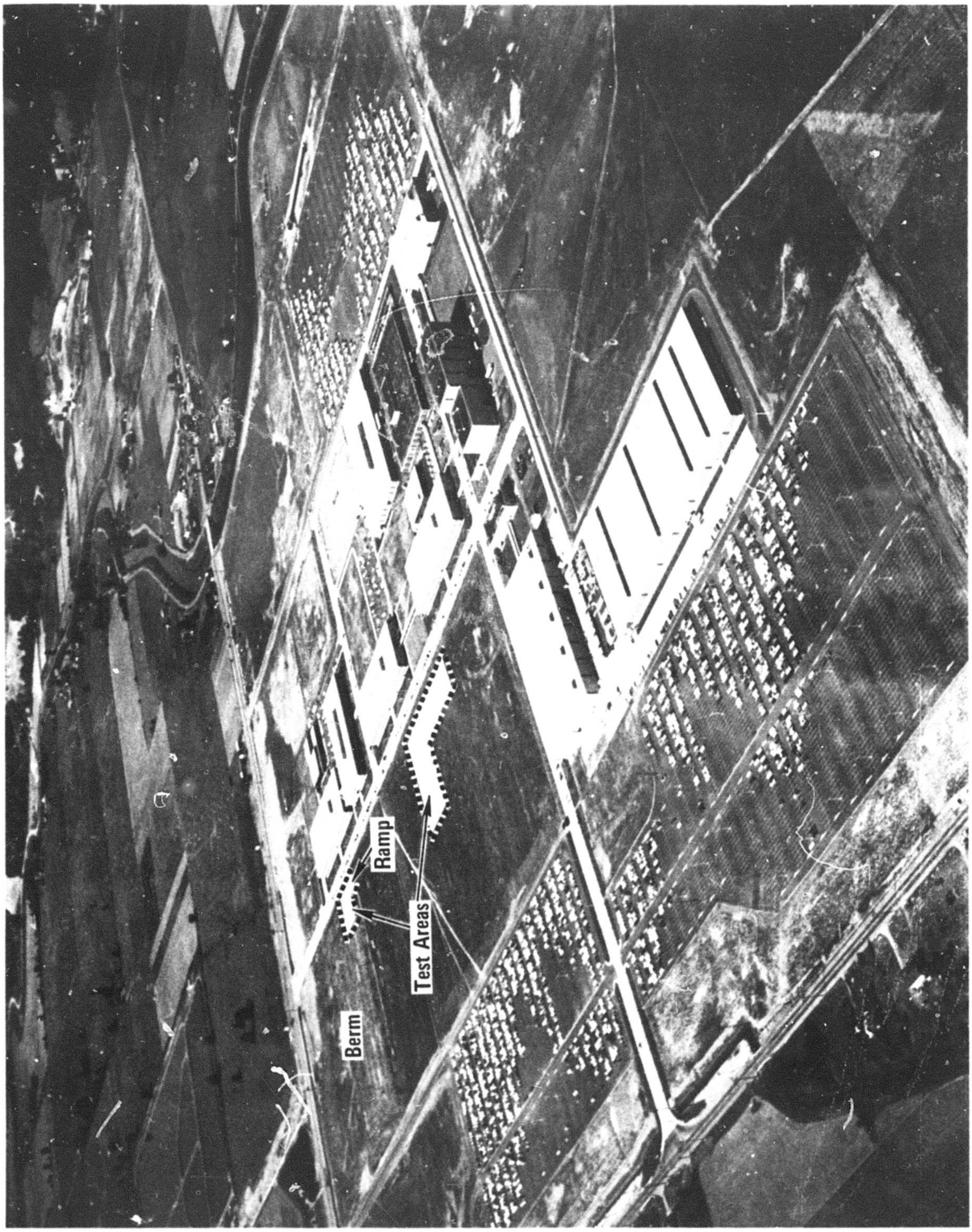


Figure 91 : TEST SITE AREA

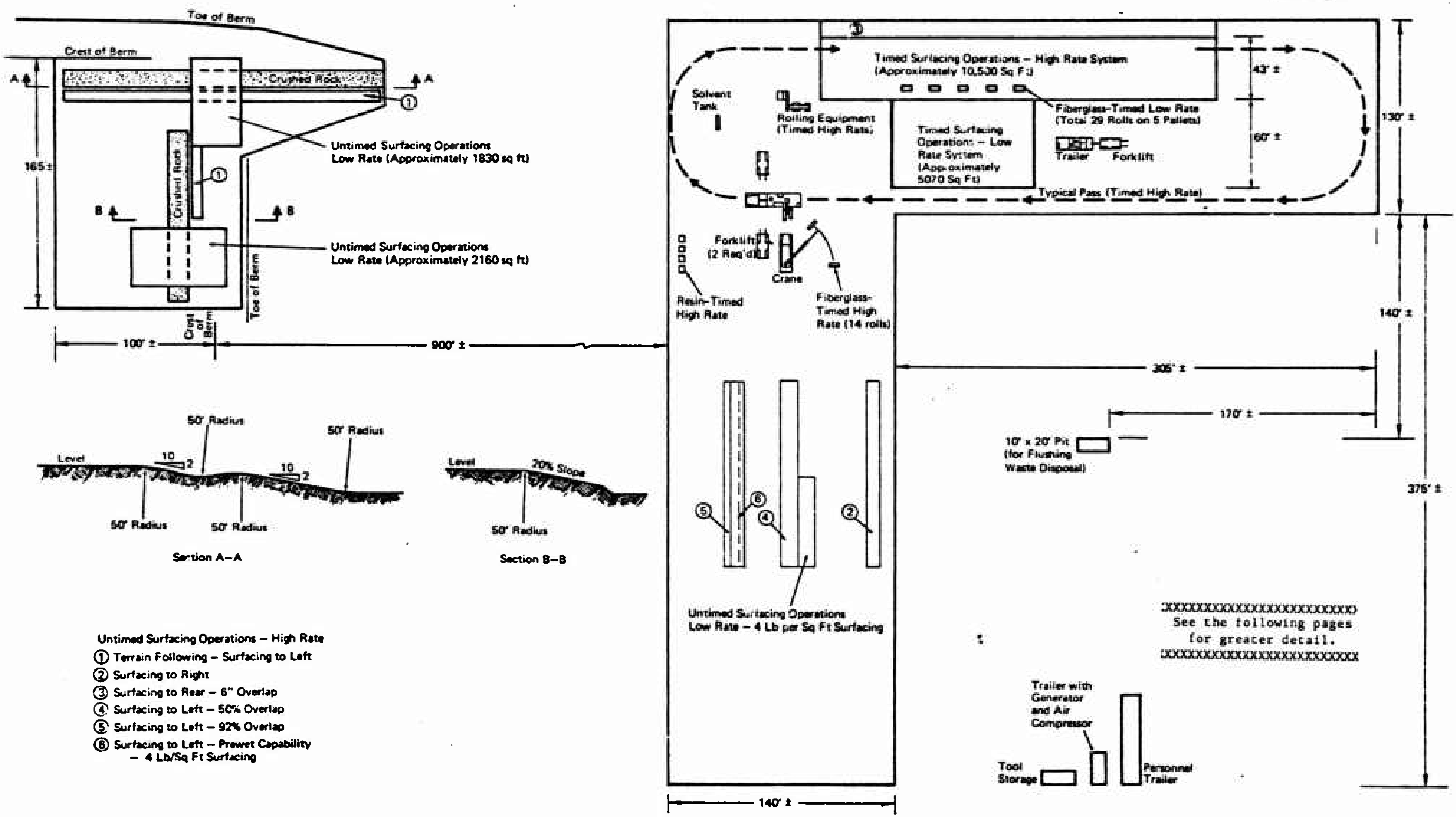


Figure 92: TEST SITE LAYOUT

3.5.3 SURFACING MATERIALS (CONT)

Based on Government recommendations this estimate was revised to incorporate two additional weights of fiberglass into the test program. All other materials used for the surfacing operations were those described in the surfacing materials verification section of this document (Reference Section 3.2). A polyester resin having a viscosity of 1600 centipoise at an approximate resin temperature of 50°F was obtained for the operational requirements testing. Table 33 shows a summary of the specific surfacing materials and their specific test usage.

3.5.4 SPECIFIC TESTS–HIGH RATE EQUIPMENT SYSTEM

A series of tests were accomplished to verify the performance capabilities of the prototype high rate equipment system. These tests (conducted at the specially constructed test site) basically consisted of untimed surfacing operations, cleaning and preparation for indefinite standby, preparation for use, timed surfacing operations and night operations. The surfacing materials used were those previously described. The ancillary equipment items obtained to support the testing (such as forklifts and crane) were based on the equipment items defined in the operational usage study. All tests were completed within the specified time periods and the performance capabilities of the high rate equipment system successfully demonstrated.

3.5.4.1 Untimed Surfacing Operations

The untimed surfacing operations demonstrated the basic system capabilities of the high rate equipment system. A total of six surfacing passes were made. PPG Industries 5000 SC19-143 resin was used in conjunction with three different weights of fiberglass reinforcement. Figure 93 summarizes these surfacing operations and Table 34 presents pertinent data applicable to these tests. Prior to beginning the surfacing operations, surfacing materials were loaded on the equipment and all fluid systems checked out.

The first surfacing pass was accomplished to demonstrate the terrain following capability of the surfacing equipment. For this pass, the equipment was in its normal surfacing configuration; i.e., boom to the left. Two, 250 foot rolls of Fab Mat C 24-15 (approximately 0.26 lbs per sq ft) fiberglass reinforcement were used. Approximately 200 lineal feet of surfacing was applied over terrain that included vertical slopes of 20%, vertical curves of 50 foot radii, and mound-like surfaces with 50 foot radii. Figure 94 shows a portion of this surfacing operation. An additional 50 lineal feet of surfacing was applied over terrain having a 20% side slope as illustrated in Figure 95. The equipment successfully negotiated all terrain encountered. Resin run-off from the curved and sloped portions of the mat was much less than expected and the cured surfacing appeared uniform.

After the first surfacing pass the surfacing equipment was configured for surfacing operations to the right. Two rolls of 0.26 lb per sq ft fiberglass reinforcement were used. Approximately 125 lineal feet of surfacing was applied as shown in Figure 96. No apparent difficulties were experienced by either the vehicle operator or the equipment operator during this "non-normal" surfacing operation.

Table 33: MATERIALS USAGE

Material	Designation	Used For
Polyester Resin	PPG Ind. 5000 SC 19-143	All Untimed Surfacing Operations
	PPG Ind. RS 50130	Operational Requirements Testing.
	Hooker Chemical 26540	All Timed Surfacing Operations.
Catalyst	Noury Corp. S0046 Green	All Tests
Promoter	Dimethyl Aniline	All Surfacing Tests
Cleaning Solvent	Methylene Chloride	All Cleaning Operations
Fiberglass Reinforcement	Fiberglass Industries:	
	Fabmat C 40-20	All Timed Surfacing Operations and 1/3 Untimed Surfacing Operations.
	Fabmat C 24-15	1/3 Untimed Surfacing Operations
	Fabmat C 16-10	1/3 Untimed Surfacing Operations

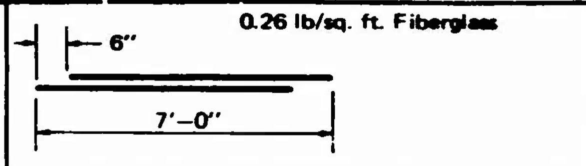
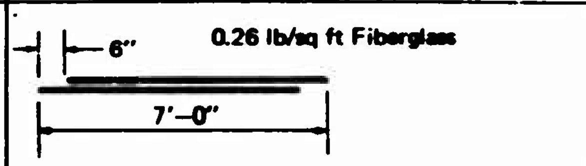
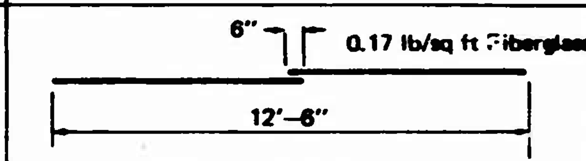
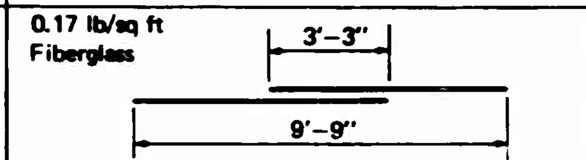
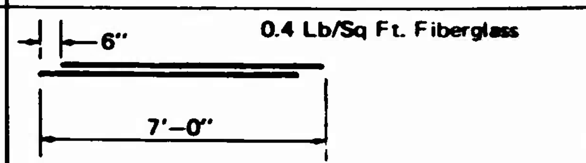
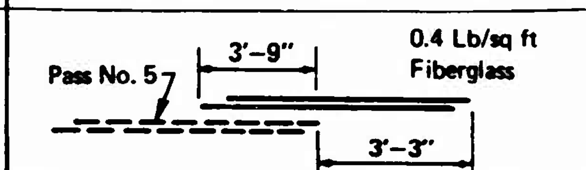
Pass No.	Equipment Capability Demonstrated	Surfacing Cross-Section	Surfaced Area (Sq. Ft.)
1	o Surfacing to Left o Terrain Following		1750
2	o Surfacing to Right o 1–1/3 Lb/Sq. Ft. Surfacing		875
3	o Surfacing to Rear o 6" Overlap o 0.43 Lb/Sq Ft. Surfacing		3125
4	o Surfacing to Left o 50% Overlap o 0.86 Lb/Sq Ft. Surfacing		1219
5	o Surfacing to Left o 92% Overlap o 2 Lb/Sq Ft Surfacing		875
6	o Surfacing to Left o Prewet Capability o 4 Lb/Sq Ft Surfacing		406

Figure 93: HIGH-RATE EQUIPMENT SYSTEM – UNTIMED SURFACING OPERATIONS

Table 34: ***UNTIMED SURFACING OPERATIONS – HIGH RATE SYSTEM***

Weather:	Sunny
Air Temperature:	76°F – 85°F
Ground Temperature:	85°F – 100°F
Resin Temperature:	68°F – 76°F
Engine Setting (RPM):	1800
Promoter Setting: (% of Stroke)	46 (Passes 1–4) 40 (Passes 5–6)
Catalyst Setting: (% of Stroke):	12 (Passes 1–4) 10 (Passes 5–6)
*** Materials Consumed: (Approximate)**	
Resin:	7800 Lbs
Promoter:	56 Lbs
Catalyst:	102 Lbs (Emulsion)
Surfacing Cure Time: (Minutes – Approximate)	12–15

* Based on actual surfacing time – Does not include materials consumed during systems checkouts.

Figure 94: SURFACING – TERRAIN FOLLOWING

Figure 95: SURFACING - 20% SLOPE

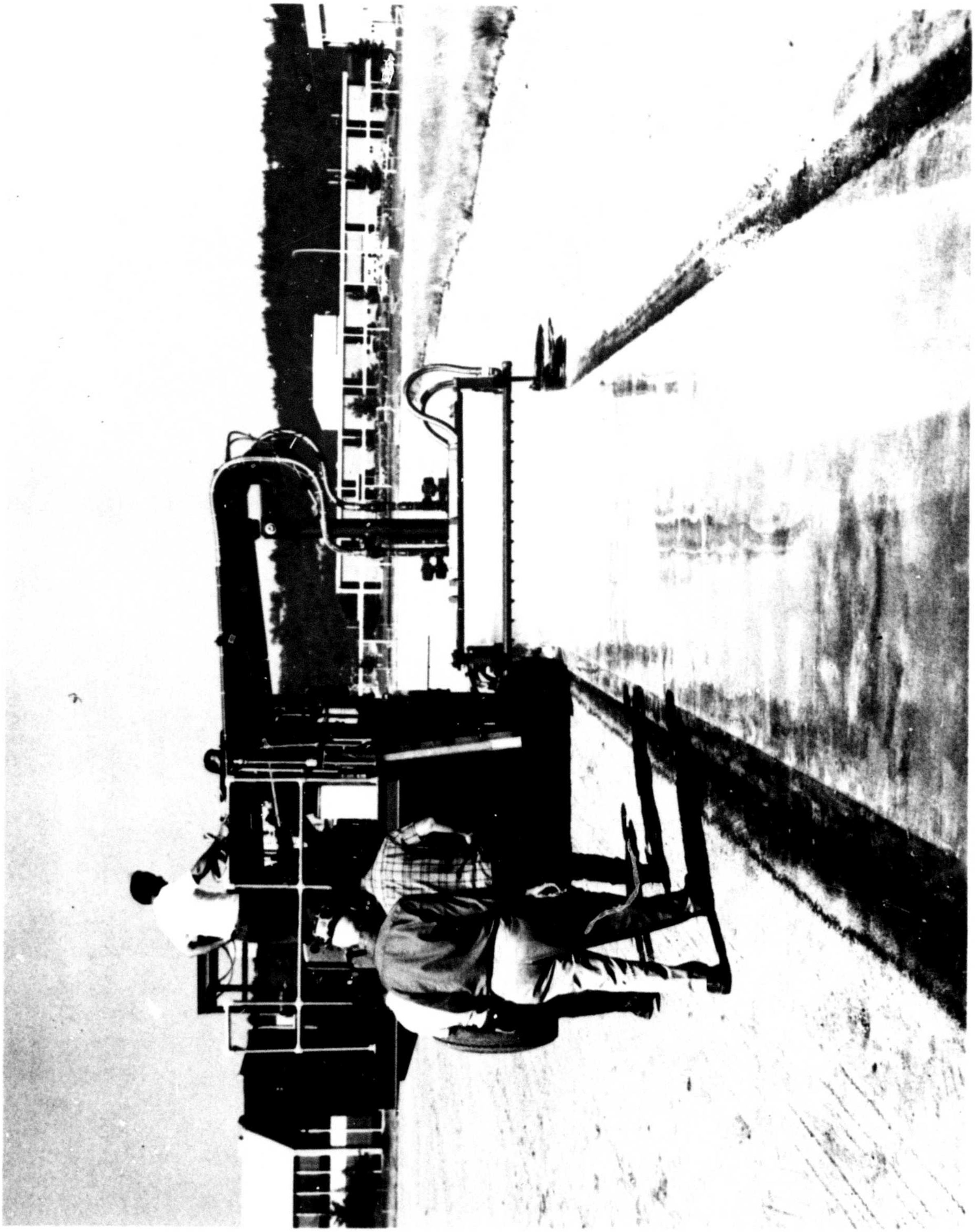


Figure 96: SURFACING TO RIGHT

3.5.4.1 Untimed Surfacing Operations (Cont)

For the next surfacing operation the boom was positioned to the rear of the truck. The glass support arm extensions were installed and the spraybar and fiberglass support assemblies adjusted for the minimum 6-inch surfacing overlap. Two rolls of Fab Mat C 16-10 (approximately 0.17 lb per square foot) fiberglass reinforcement (shown being loaded in Figure 97) were used for this test. Approximately 250 lineal feet of surfacing was applied as shown in Figure 98. Again no operational problems were encountered and a satisfactory surface resulted.

The fourth surfacing pass as illustrated in Figure 99 successfully demonstrated surfacing to the left and 50% surfacing overlap. The truck boom had been positioned to the left and the spraybar-fiberglass support structure positioned for the 50% overlap condition. Two rolls of 0.17 lb per square foot fiberglass reinforcement were used and approximately 125 lineal feet of surfacing applied.

The fifth and sixth surfacing passes were accomplished to demonstrate normal surfacing operations, pre-wet capability, and construction of a 4 lb per square foot mat. For this demonstration the spraybar glass support structures were positioned for 92% overlap and the glass support arm extensions removed. Two rolls of Fab Mat C 40-20 (approximately 0.4 lb per square foot) fiberglass reinforcement were used for each surfacing pass. 125 lineal feet of nominal 2 lb per square foot surfacing were applied during the fifth surfacing pass as shown in Figure 100. For the sixth surfacing pass the pre-wet nozzles were used. These nozzles (located as shown in Figure 58) are normally used to apply promoted and catalyzed resin to a previously cured surface so that adequate bonding occurs between the old surface and that being applied. Application of 125 lineal feet of nominal 2 lb per square foot surfacing is shown in Figure 101. This figure also shows the overlap between the two 2-lb per square foot mats that achieves the required 4 lb per square foot surface. Figure 102 shows the sixth strip being rolled and is typical of the rolling operations conducted during this test.

Both surfaces were satisfactory, however, during the fifth surfacing pass the on-board materials tender neglected to switch from one resin tote to another in time and the resin flow was momentarily interrupted resulting in a small section of unwet fiberglass. After completion of the sixth pass the truck was repositioned and this area sprayed satisfactorily.

To summarize the above surfacing applications, no equipment malfunctions occurred during the tests and satisfactory cure was achieved on all surfacing. Wrinkles that did occur seemed to result from several causes: slight change in direction during a pass; misalignment of the fiberglass at the start of a pass, and looseness or differences in tension of the fiberglass roll layers as received from the supplier. Good, consistent fan angles emanated from the spraybar nozzles throughout the testing and excellent blending of the surfacing liquids was achieved. The rollers exhibited questionable effectiveness and caused some scuffing. As a result some adjustments were made to the rolling equipment (notably providing a greater degree of clearance between the roller segments) and considerable operator practice accomplished prior to the timed surfacing operation.

Figure 97 : GLASS LOADING

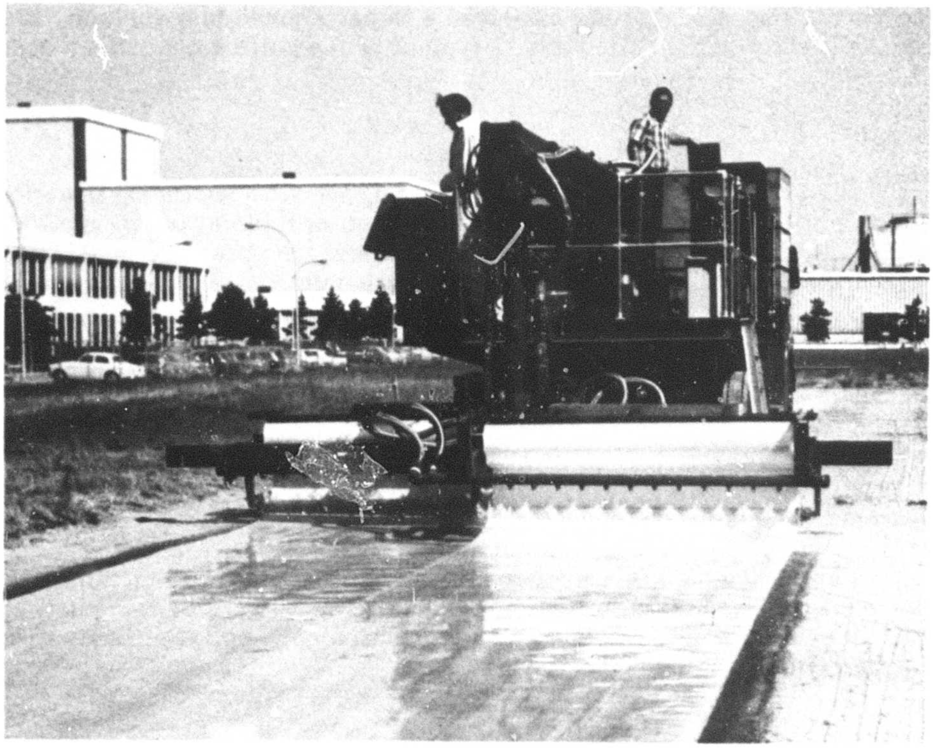


Figure 98 : SURFACING TO REAR

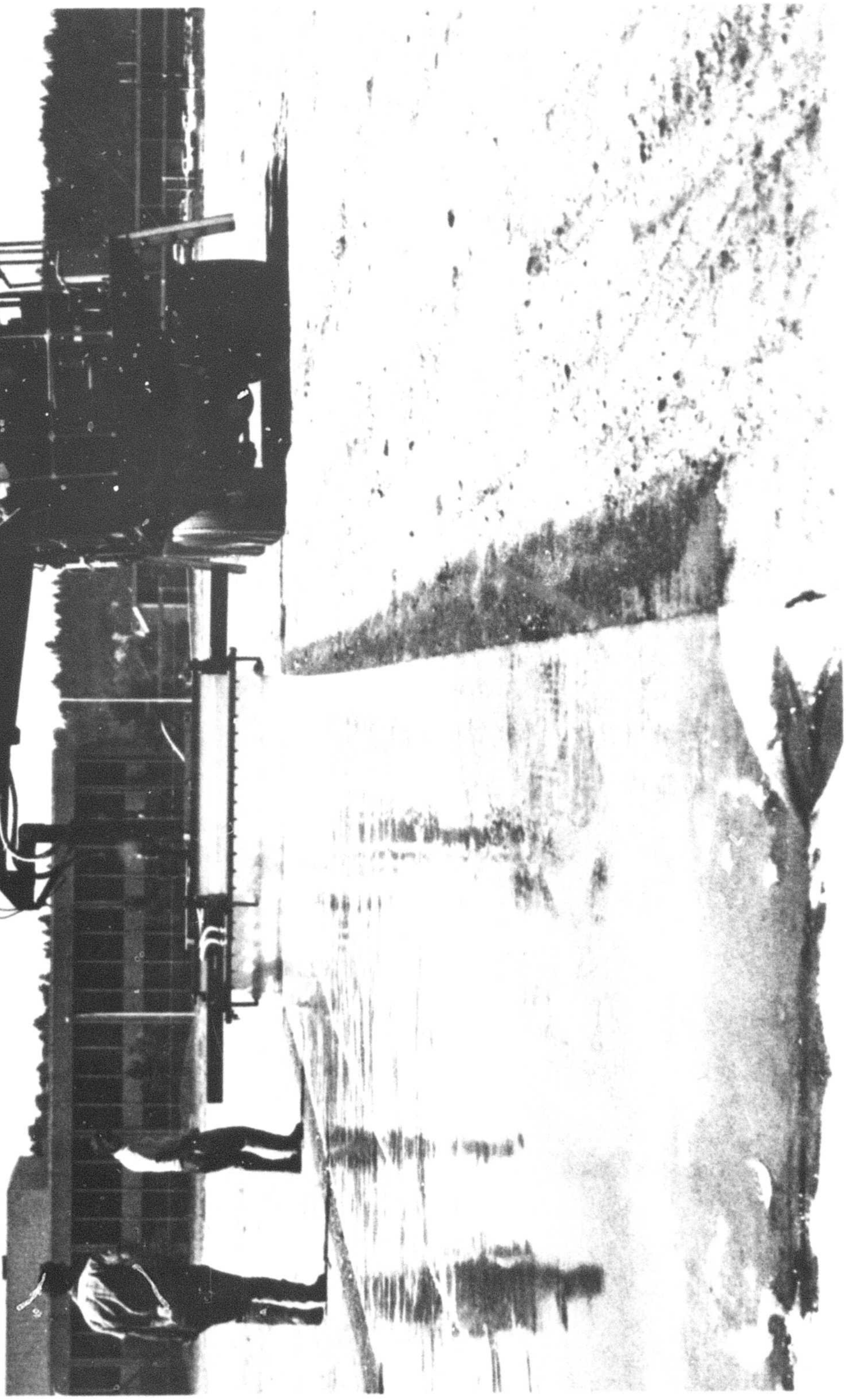


Figure 99: *SURFACING TO LEFT – 50% OVERLAP*

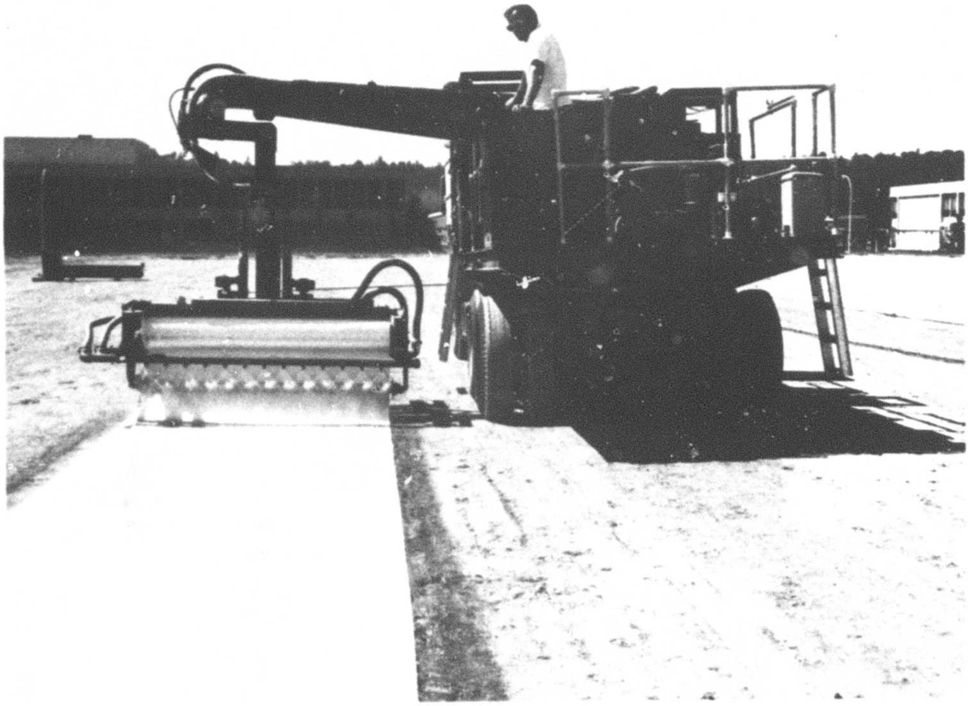


Figure 100: NORMAL SURFACING MODE

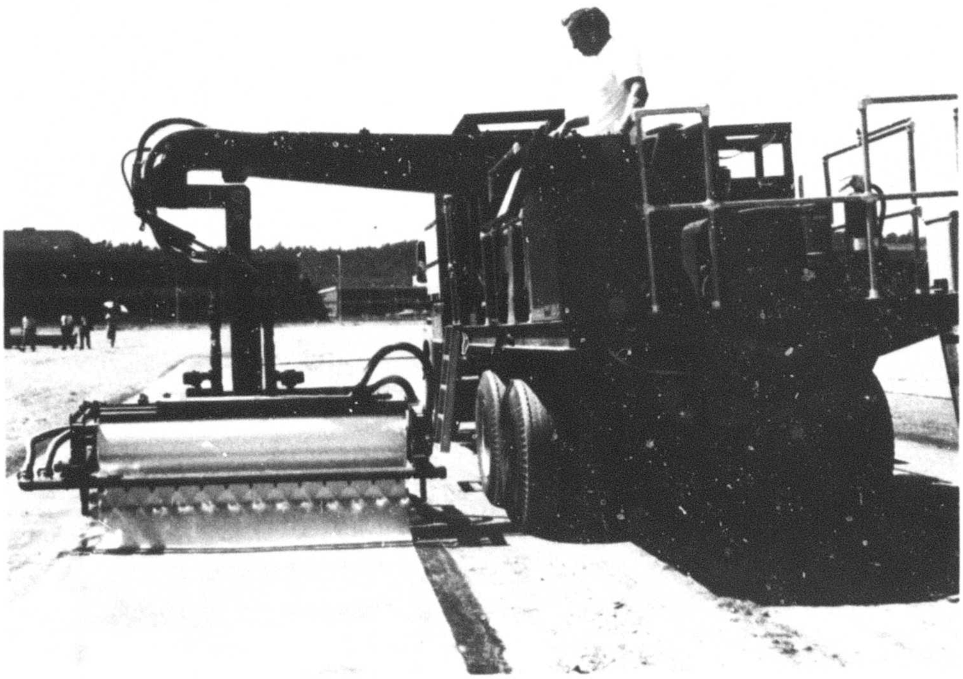


Figure 101: CONSTRUCTION OF 4-LB PER SQ FT SURFACING

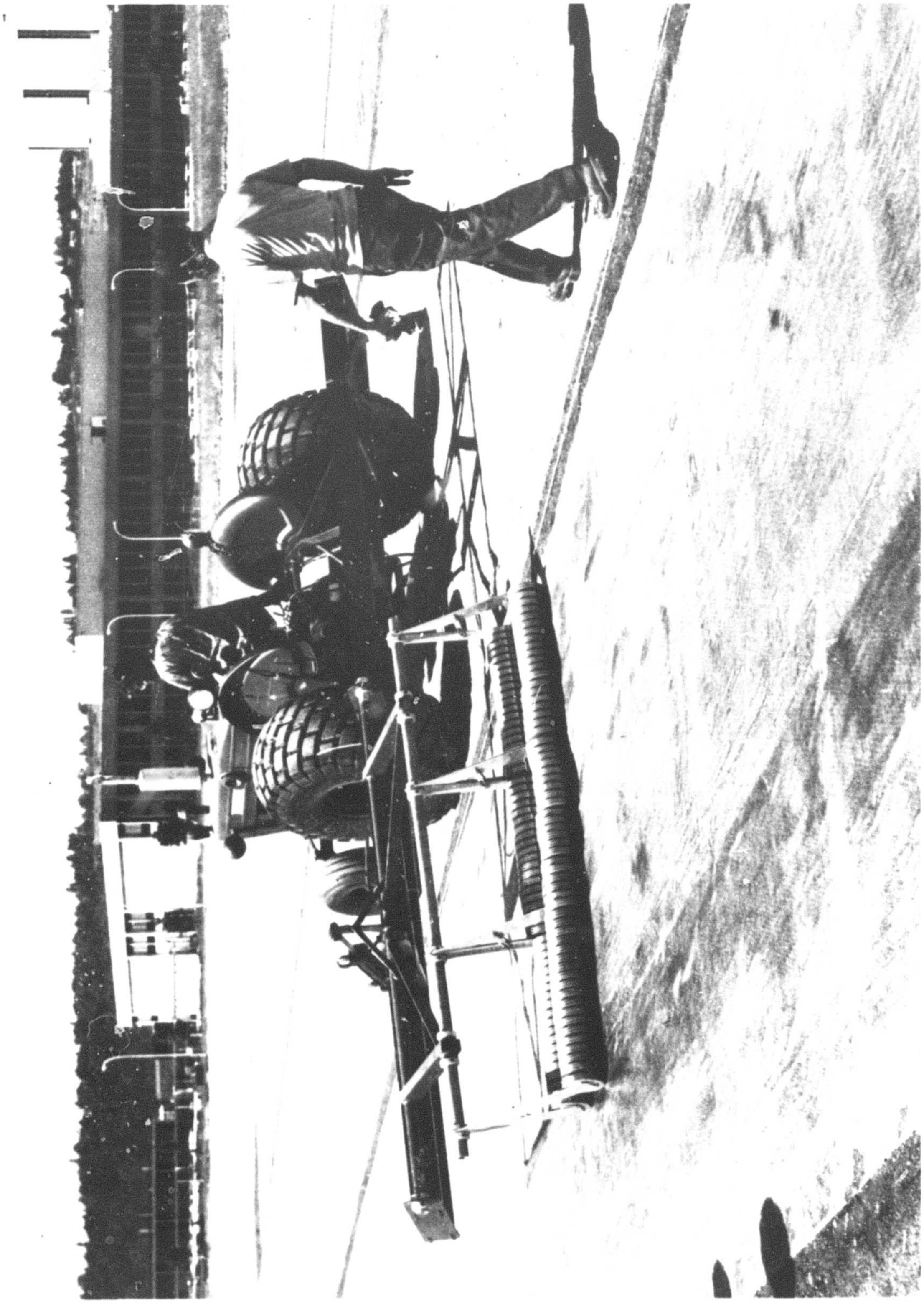


Figure 102: OPERATION OF ROLLING EQUIPMENT

3.5.4.2 Cleaning and Preparation for Indefinite Standby

After completing the untimed surfacing operations the high rate equipment system was cleaned and prepared for indefinite standby. It was required that these procedures be completed within two hours. For the cleaning portion of the test all fluid systems and systems components requiring solvent cleaning were to be flushed with methylene chloride. Wastes were to be disposed of so as to have no adverse effects on personnel, structures, or ecology.

Vehicle and other equipment items were prepared for storage following applicable procedures outlined in Section VI Active (Live) Storage of T.O. 36-1-5 (Processing of Motor Vehicles for Storage and Shipment). These procedures are directed at maintaining vehicles in an operating condition ready for immediate use during indefinite storage periods and require periodic exercise of the vehicle every 30 days.

Prior to starting the timed portion of the test the carrier vehicle was positioned at the waste pit, resin containers removed, and drums positioned for reclaiming the promoter and catalyst remaining in the hoppers.

The timed portion of this test was considered to begin with the loading of the solvent drums and their stands onto the truck. Two solvent drums in addition to the on-board solvent drum were considered necessary for cleaning. Figure 103 shows the second solvent drum being positioned on its respective stand. Concurrent with solvent loading, excess promoter and catalyst remaining in their respective hoppers were reclaimed. This was accomplished by operating the catalyst and promoter pumps independent of the resin pump and pumping the liquids through drain hoses connected to fittings on the discharge side of the pumps into the previously positioned drums. Solvent was then added to the promoter and catalyst hoppers and all liquid systems flushed with cleaning solvent. Miscellaneous system items such as the catalyst hopper cover and filter screen were cleaned with the portable solvent spraygun as shown in Figure 104. At the same time the fluid dispensing systems were being cleaned the tow tractor was positioned at the solvent trough as shown in Figure 105 and the roller discs cleaned.

After equipment cleaning both the truck and tow tractor were prepared for indefinite standby.

The following tasks as applicable to the equipment item were accomplished.

- Lubricant levels for engines, power train and liquid pumps were checked and no replenishment was required
- Cooling and hydraulic systems liquid levels were checked No replenishment was required
- All liquid pumps were greased
- Boom extension wear plates were greased
- Fuel tanks were filled to capacity
- Protective covers were installed
- A visual inspection for leaks was accomplished
- Miscellaneous equipment items were stowed

Figure 103: SOLVENT DRUM POSITIONING

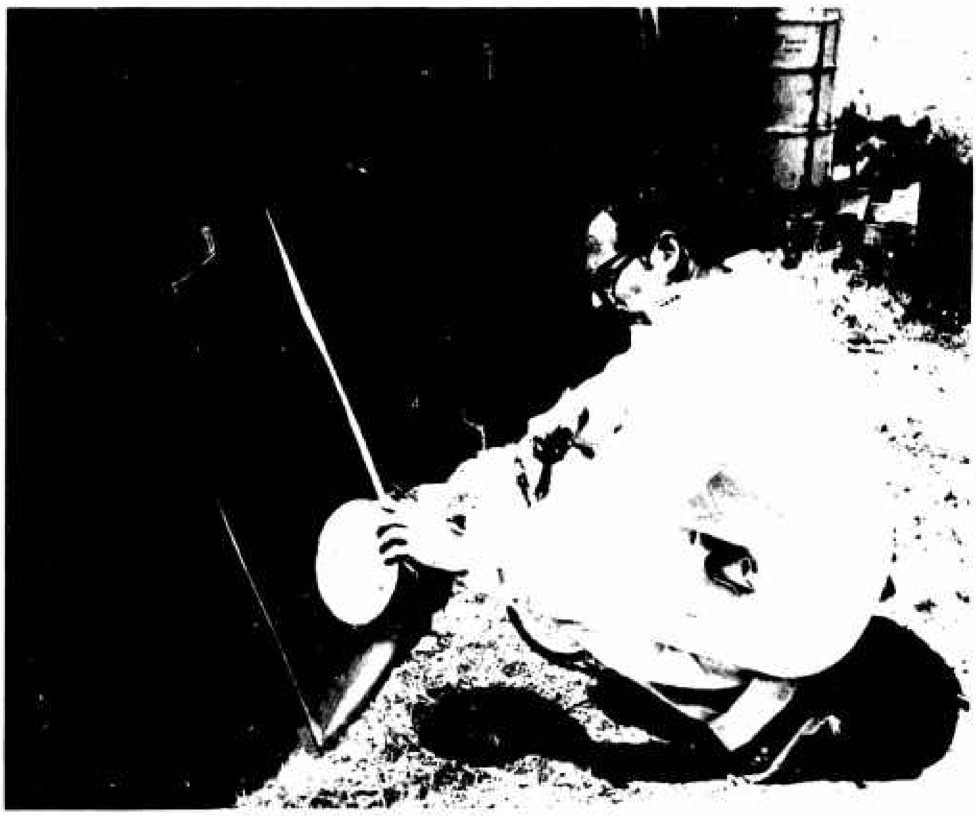


Figure 104: PORTABLE SOLVENT SPRAY GUN

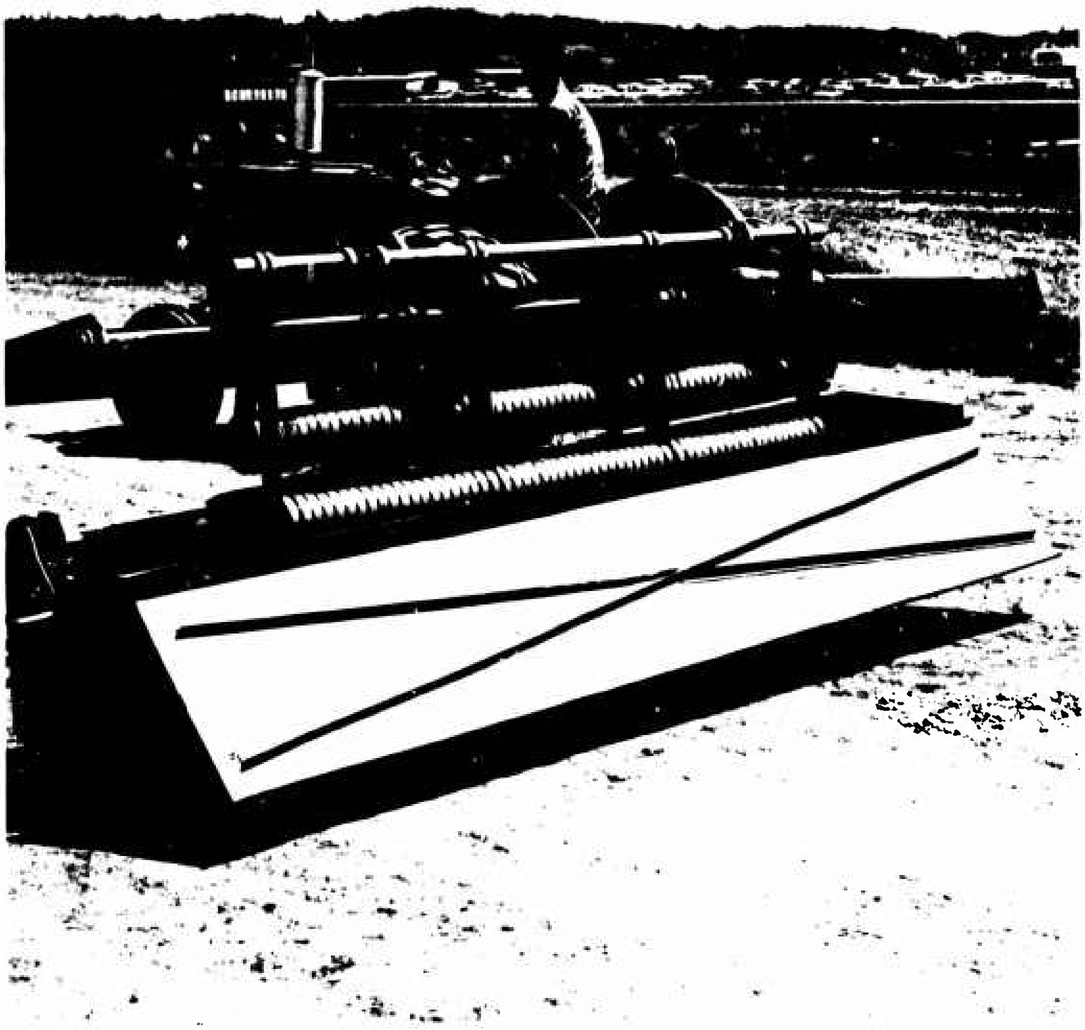


Figure 105: TRACTOR POSITIONING

3.5.4.2 Cleaning and Preparation for Indefinite Standby (Cont)

- Truck suspension system was unlocked
- Boom and Spraybar glass support structure positioned for ground transport
- Tires were marked to indicate ground contact area
- Air reservoir of the air brake system was drained
- Tractor roller assembly disconnected and set on blocks

No problems were encountered in either the cleaning or preparation for indefinite standby portions of the test. Total test time was one hour and forty-five minutes with cleaning requiring one hour and fifteen minutes and preparation for indefinite standby requiring 30 minutes.

3.5.4.3 Preparation for Use

Three days after cleaning and preparing the equipment for indefinite standby it was brought to a ready-to-use condition. It was required that this test be completed within two hours and the condition of the equipment be such that surfacing operations could be resumed.

The following tasks as applicable to the equipment item were accomplished:

- Visual inspection for damaged loose or missing parts
- Visual inspection for fuel, oil, hydraulic fluid or coolant leakage
- Fuel, oil, lubricant, coolant, battery water levels were checked
- Fan belts were checked
- Boom hydraulic fluid level was checked
- Tire pressures were checked
- Promoter and catalyst pump oil levels were checked
- All liquid pumps were greased
- Boom extension wear plates were greased
- Brakes, lights, horn and reflectors checked
- Truck suspension system was locked out
- Boom and turret were operated in all modes
- All pump drive systems were operated
- Remaining control panel items were checked and operated
- Spraybar nozzles were checked for alignment

No problems were encountered and the test was completed in one hour and five minutes.

3.5.4.4 Timed Surfacing Operations

The requirements for the timed surfacing operations were to apply 10,000 square feet of 2 lb per square foot surfacing within one hour with no more than 9 personnel working at any one time. The surfacing materials used for this test were Hooker Chemical 26540 polyester resin and 0.4 lb per square foot, 250 feet long by 6.5 feet wide fiberglass reinforcement. Prior to beginning the test the surfacing materials and solvent tank were positioned as shown in Figure 92. Two resin containers and two rolls of glass were loaded and all fluid systems checked out. Clock time for this test was considered to begin with the application of the first surfacing strip. Table 35 presents pertinent data applicable to this test. Figures 106 through 110 show operations conducted during the test.

A total of seven passes utilizing two rolls of 250 feet long fiberglass reinforcement per pass were made. All strips were subjected to rolling by the rolling equipment. Approximately 10,500 square feet of surfacing was applied. Starting with the application of the first surfacing strip and ending with the rolling of the seventh strip. A total time of slightly under 46 minutes was required for the timed surfacing operation.

No equipment malfunctions occurred during this test and an excellent cured surface was obtained. Bonding between adjacent strips appeared good. The surfacing rollers appeared more effective than expected and very satisfactory results were obtained using the rollers.

3.5.4.5 Night Operations

After completing the timed surfacing operations the equipment was readied for night operations. The purpose of this test was to determine the adequacy of the lighting provided for surfacing operations conducted at night. Two 125-foot long rolls of 0.4 lb per square foot fiberglass reinforcement and PPG Inds 5000 SC19-143 resin were used as the surfacing materials. For this operation the aft pair of spraybars was shut off and all resin dispensing accomplished with the forward pair of spraybars. One 125-foot length of surfacing was applied from the left of the truck. The other 125-foot length of surfacing overlapping the previously applied strip by approximately 12 inches was also applied from the left side of the truck. Both strips were rolled with the rolling equipment.

During night operation the catalyst pump drive was engaged while the valve in the outlet line was inadvertently left in the closed position. This caused the pump relief valve to open and it required several minutes to re-seat the valve. Three spraybar nozzles were also observed to be plugged during surfacing.

Subsequent to test and clean-up, it was discovered that failure had occurred in the surfacing rollers support structure where several aluminum welds separated. The faulty section was re-designed, fabricated, and tested prior to equipment delivery.

The illumination provided on both the truck and tractor were considered adequate for night surfacing operations. It is considered that total night construction operations would necessarily employ total area lighting.

Table 36: TIMED SURFACING OPERATIONS – HIGH RATE SYSTEM

Weather:	Sunny
Air Temperature:	81°F – 83°F
Ground Temperature:	97°F – 100°F
Resin Temperature:	81°F
Engine Setting (RPM):	1700
Promoter Setting: (% of Stroke)	34 (Passes 1–3) 48 (Passes 4–7)
Catalyst Setting: (% of Stroke)	12 (Passes 1–3) 20 (Passes 4–7)
* **Materials Consumed:** (Approximate)	
Resin:	13,300 Lbs
Promoter:	85 Lbs
Catalyst:	235 Lbs (Emulsion)
Surfacing Cure Time: (Minutes – Approximate)	20–25 (Passes 1–3) 12–18 (Passes 4–7)

* Based on surfacing time – Does not include materials consumed during systems checkouts.

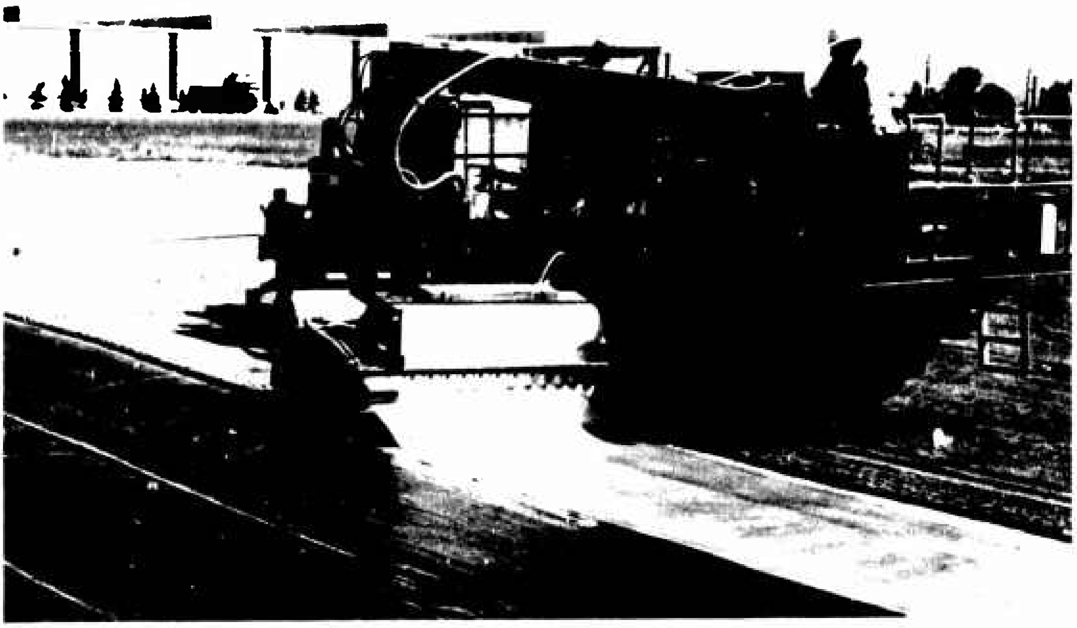


Figure 106: TYPICAL SURFACING OPERATION – 4TH PASS

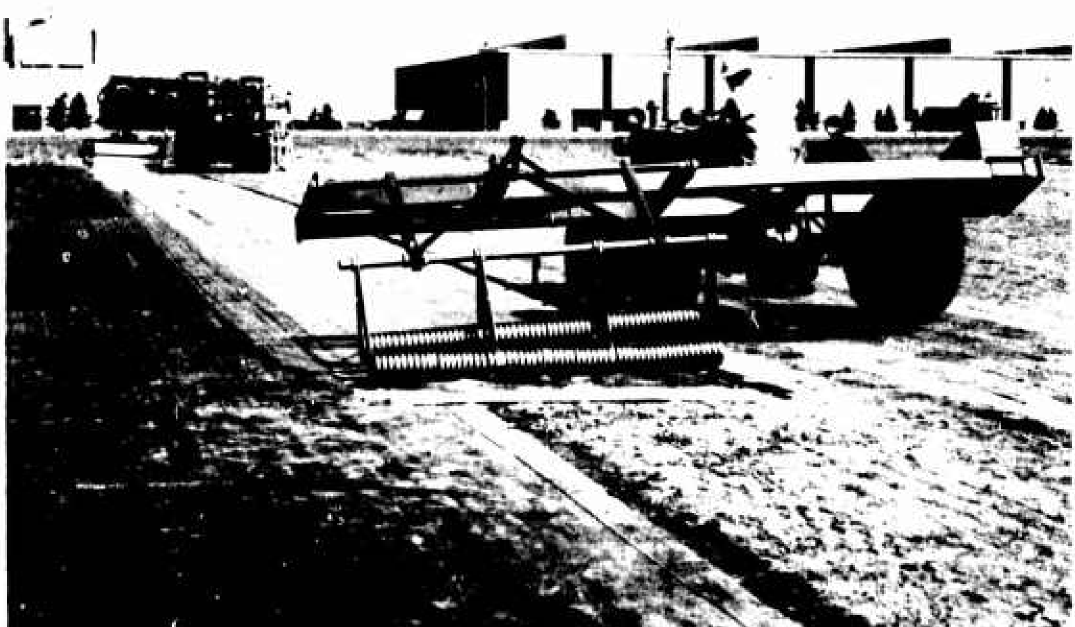


Figure 107: POSITION ROLLERS

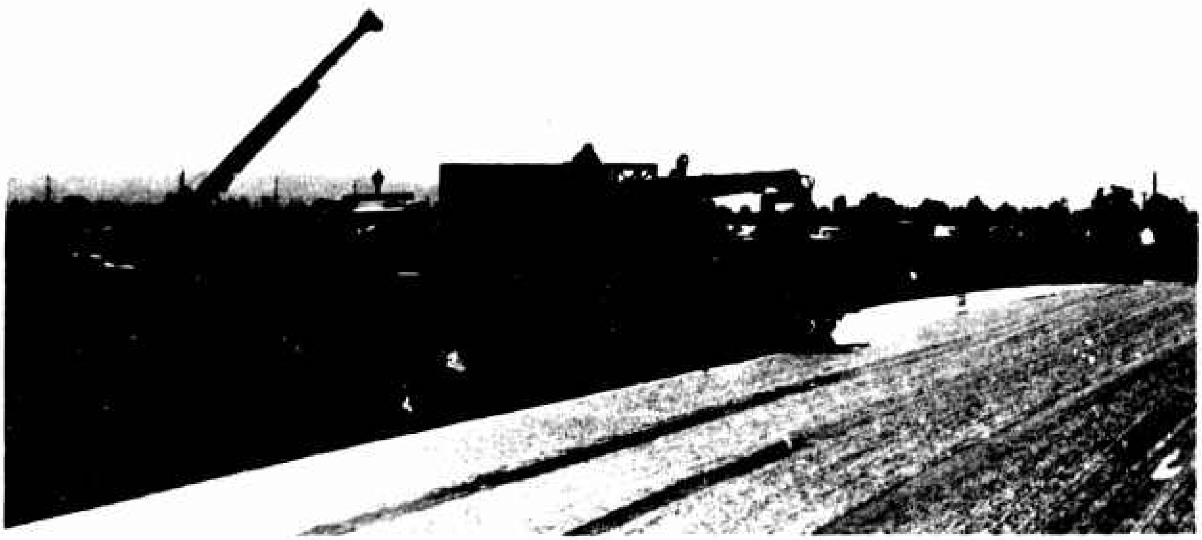


Figure 108: TYPICAL SURFACING OPERATION – 6TH PASS

Figure 109: TYPICAL ROLLING OPERATION

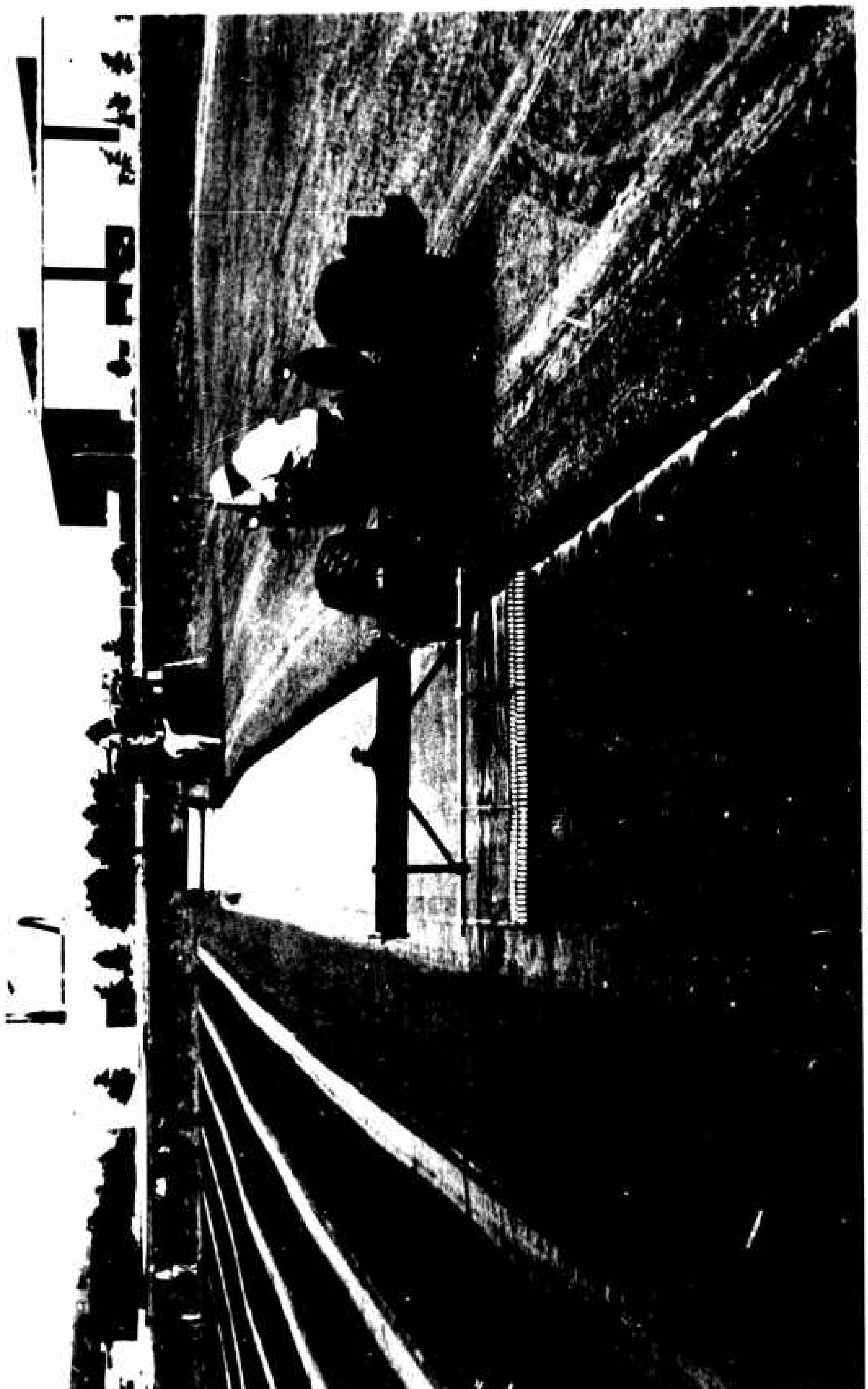


Figure 110: TYPICAL SURFACING SEQUENCE – 7TH PASS

3.5.5 SPECIFIC TESTS – LOW RATE EQUIPMENT SYSTEM

This series of tests were accomplished to verify the performance capabilities of the prototype low rate equipment system. These tests were also conducted at the specially constructed test site. As was the case with high rate equipment system tests, these tests consisted of untimed surfacing operations, cleaning and preparation for indefinite standby, preparation for use, timed surfacing operations, and night operations.

The surfacing materials used have been previously described. Surfacing procedures and ancillary equipment used were based to a large extent on the operational usage study. All tests were completed successfully and within the specified time periods.

3.5.5.1 Untimed Surfacing Operations

The untimed surfacing operations were performed to demonstrate basic equipment capability. PPG Industries 5000 SC19-143 resin and three different weights of fiberglass were the surfacing materials used for this test. Prior to beginning the surfacing operations, liquid surfacing materials were loaded on the trailer, the fluid systems checked out, and the fiberglass reinforcement prepositioned at the areas to be surfaced.

For the first major portion of this surfacing operation the trailer was positioned on the 20% side slope. Approximately 2,160 square feet of surfacing was applied and consisted of 6 rolls of 6.5 wide by 60-foot long fiberglass. Each strip overlapped the previously applied strip 6 inches. One-third of the surfacing was constructed from 0.4 lb per square foot reinforcement, one-third from 0.26 lb per square foot reinforcement and the remaining third from 0.17 lb per square foot reinforcement.

The second major portion of this surfacing operation consisted of applying surfacing materials over curved, mound-like, rough and uneven surfaces. Five rolls of 6.5 foot wide by 60 feet long fiberglass were used and each strip overlapped the previously applied strip by 6 inches. A total of approximately 1,830 square feet of surfacing was applied. The fiberglass used for the first strip weighed 0.4 lb per square foot and two each of the remaining four strips were the lighter weight reinforcement previously mentioned.

In addition to the above surfacing operations an additional 660 square feet of surfacing was applied to demonstrate construction of 4 lb per square foot surfacing. This operation consisted of applying four strips of 6.5 feet wide by 60-feet long 0.4 lb per square foot fiberglass and overlapping the previously applied strip 18 inches to obtain the required 4 lb per square foot surfacing. These strips were rolled with the hand roller.

Figures 111 through 114 are illustrative of the surfacing operations accomplished during this test. Table 36 presents applicable test data.

The equipment system successfully demonstrated negotiation and surfacing of terrain with 50-ft radii, 20% slopes, and surfacing over rough terrain. All weights of surfacing applied cured satisfactorily and good wearing surfaces were obtained. No equipment malfunctions occurred during the application of approximately 4,600 square feet of surfacing.

Figure 111: GLASS DISPENSING

Figure 112: LIQUID DISPENSING – 20% SLOPE

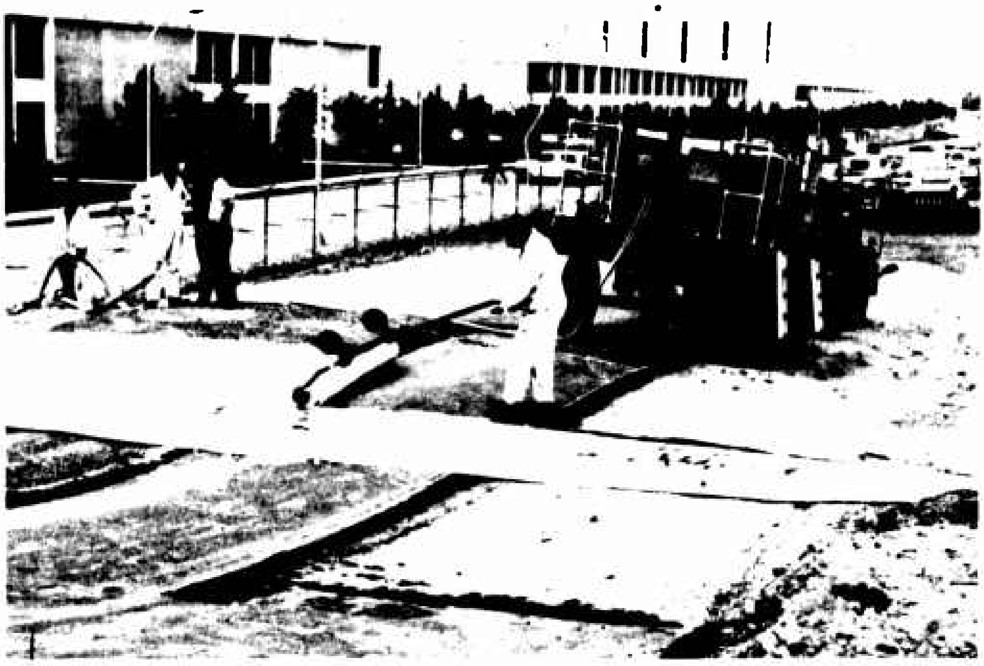


Figure 113: *GLASS DISPENSING – CURVED SURFACES*

Figure 114: *LIQUID DISPENSING – CURVED SURFACES*

Table 36: UNTIMED SURFACING OPERATIONS – LOW RATE SYSTEM

Weather:	Cloudy – Partly Sunny
Air Temperature:	68°F – 73°F
Ground Temperature:	68°F – 81°F
Resin Temperature:	61°F – 62°F
Engine Setting (RPM):	3150 (Surfacing Strips 1 – 5)
	3350 (Remainder of Test)
Promoter Setting:	29 (Surfacing Strips 1 – 8)
(% of Stroke)	22 (Surfacing Strips 9 – 11)
	18 (Surfacing Strips 12 – 15)
Catalyst Setting:	44 (Surfacing Strips 1 – 6)
(% of Stroke)	40 (Surfacing Strips 7 – 8)
	32 (Surfacing Strips 9 – 11)
	30 (Surfacing Strips 12 – 15)
*Materials Consumed	
(Approximate)	
Resin	3,000 Lb
Promoter	27 Lb
Catalyst	48 Lb (Emulsion)
Surfacing Cure Time:	6 – 8 (Surfacing Strips 1 – 8)
(Minutes – Approximate)	7 – 9 (Surfacing Strips 9 – 10)
	8 – 10 (Surfacing Strips 12 – 15)

*Does Not Include Materials Consumed During Systems Checkouts

3.5.5.1 Untimed Surfacing Operations (Cont)

During the early portion of the test several spraybar nozzles became plugged and were replaced. It was observed during surfacing that blending of the liquids did not appear as uniform as with the high rate system. However, satisfactory surfaces with complete cure were achieved. It was also observed that the hand roller, operated diagonally to the length of surfacing, did not appear as effective as the high rate system rolling equipment.

3.5.5.2 Cleaning and Preparation for Indefinite Standby

After completion of the untimed surfacing operations the low rate equipment was cleaned and prepared for indefinite standby. The time alloted for this test was two hours.

All fluid systems and systems components requiring solvent cleaning were flushed with methylene chloride. All wastes were disposed of in the least harmful manner to personnel, structure, or ecology. The equipment items were prepared for storage in a manner similar to that previously described.

Similar to the cleaning accomplished with the high rate equipment system the trailer was positioned at the waste pit, resin containers removed, and promoter and catalyst reclamation drums positioned prior to starting the timed portion of the test.

The timed portion of the test was considered to start with the connection of the resin suction line to the solvent barrel manifold. The remaining cleaning operation consisted of draining excess promoter and catalyst from the hoppers, solvent flushing of liquid systems and cleaning miscellaneous system components such as the hand rollers.

After cleaning the trailer and related equipment items were prepared for indefinite standby. The following tasks were accomplished:

- All liquid pumps were greased
- All pump and engine lubricant levels were checked
- Fuel tank filled to capacity
- Battery water level was checked
- All equipment items were stowed
- Protective covers were installed
- Tires marked to indicate ground contact area
- Visual inspection for evidence of leaks

No problems were encountered in either the cleaning or preparation for indefinite standby portions of this test. The total time required for this test was one hour and 20 minutes; well within the alloted time.

3.5.5.3 Preparation for Use

Two days after cleaning and preparation for indefinite standby the trailer and related equipment items were prepared for use. As with the high rate equipment, the condition of the equipment was to be such that surfacing operations could be resumed within two hours.

The following tasks were accomplished as part of this test

- Trailer and other equipment items were visually inspected for loose, damaged or missing parts
- A visual inspection was made for evidence of fuel, oil, lubricant or hydraulic fluid leakage
- Fuel, oil, battery water levels were checked
- Tire pressures were checked
- Promoter/catalyst pump oil level checked
- All liquid pumps were greased
- All liquid pump drive systems were operated
- All control panel items checked and operated as required
- Trailer was hooked to a tow vehicle and the brakes, lights, and reflectors checked

This test was accomplished in sixteen minutes and no problems were encountered.

3.5.5.4 Timed Surfacing Operations

This test required the application of 5,000 square feet of 2 pound per square foot surfacing at a rate of 2,000 square foot per hour with no more than five personnel working at any one time. The resin surfacing materials used for this test were Hooker Chemical 26540 polyester resin and PPG IND's 5000 SC19-143 polyester resin. All fiberglass reinforcement weighed 0.4 lbs per square foot and was 6.5 feet wide by 60 feet long.

Before beginning the timed portion of this test two totes containing 26540 resin and the promoter and catalyst were loaded on the trailer. Fiberglass reinforcement was prepositioned at the test area as indicated in Figure 92 and all fluid systems were checked out. Clock time for this test was considered to begin with the application of the first surfacing strip. Table 37 presents data pertaining to this test.

Table 37: TIMED SURFACING OPERATIONS – LOW RATE SYSTEM

Weather:	Cloudy (Intermittent Showers)
Air Temperature:	64°F
Ground Temperature:	68°F
Resin Temperature:	59°F
Engine Setting (RPM):	3000
Promoter Setting: (% of Stroke)	29
Catalyst Setting: (% of Stroke)	30
*Materials Consumed (Approximate)	
**Resin:	6,900 Lb
Promoter:	63 Lbs
Catalyst:	133 Lb (Emulsion)
Surfacing Cure Time (Minutes – Approximate)	15 – 20 (Surfacing Strips 1 – 25)
	8 – 10 (Surfacing Strips 26 – 29)

*Does Not Include Materials Consumed During Systems Checkout

**Includes 900 Lb Resin 5000 SC 19-143 Used For Surfacing Strips 26 – 29

3.5.5.4 Timed Surfacing Operations (Cont)

A total of twenty-nine surfacing strips were applied during this test. Each strip overlapped the previously applied strip by 3.5 feet to obtain the required 2 pound per square foot surfacing. All liquids were dispensed with the hand held spraybar and surfacing was rolled with the hand held roller. Approximately 5,070 square feet of surfacing was applied in approximately two hours and five minutes.

During this test the trailer was repositioned after applying the eighth and eighteenth surfacing strips. Resin was drawn from the left tote for the first twelve surfacing strips and from the right tote for the next thirteen strips. When repositioning the trailer after applying the eighteenth surfacing strip the left tote was removed and a new tote containing 5000 SC19-143 resin loaded onto the trailer. Resin was drawn from this tote when applying the last four surfacing strips.

It was observed that the resin delivery hoses could easily accommodate surfacing over an area of 50 ft radius without moving the trailer. During the surfacing operation several spraybar nozzles became plugged during the early part of the operation and were replaced. Also, during surfacing, the spring clip which secures the pump drive sprocket chain connecting links fell out, thus allowing the chain to separate. Approximately 12 minutes were required to reconnect the chain, replace the clip and resume surfacing. This 12 minute interruption in surfacing is included in the two hours and five minutes. This was not considered an equipment malfunction such as would prevent successful completion of the test. It did, however, indicate that for reliability, close inspection in this area as well as spare chains are required.

It was also observed that as in the untimed surfacing operation, the hand roller did not appear as effective as the high rate system rolling equipment. However, the resulting surface appeared to be satisfactory and entirely usable.

Prior to beginning the timed portion of the test during fluid system checkout, residue was found in the resin/catalyst mixing chamber which took some time to remove. Subsequent to surfacing operations the chamber was inspected and it was found that the chamber drain pipe protruded above the chamber wall thus preventing complete system drainage during cleaning operations. This chamber was removed and reworked prior to equipment delivery. The existing drain was capped and a new drain installed 180 degrees from the existing drain. The new drain consists of a bushing (for drain fitting attachment) welded to the chamber outer wall and centered over a drilled hole in the chamber wall. The chamber was then reinstalled in the fluid system. As a result of the blockage that occurred in the catalyst resin mixing chamber the promoter resin mixing chamber was inspected to determine if the chamber drain pipe was interfering with system cleaning operations. Examination revealed satisfactory installation of the drain pipe with no protrudence above the chamber wall thus eliminating the need for rework of this mixing chamber.

3.5.5.5 Night Operations

Night operations were conducted after completion of the timed surfacing operations to verify adequacy of the lighting system provided. Two 6.5 foot wide 60 foot rolls of 0.4 lb per square foot fiberglass and PPG IND's 5000 SC19-143 resin were used as the surfacing materials. For this operation the hand held spraygun rather than the hand held spraybar was used to dispense the liquid surfacing materials.

Approximately 500 square feet of surfacing was applied. Sufficient illumination was provided by the trailer lights and by the portable battery powered head lamps to allow glass dispensing, liquid dispensing and glass rolling.

The basic lighting system appeared adequate. However, the lighting system circuit breaker was of insufficient capacity (7 amps) and caused interruption in lighting. The circuit breaker was replaced with one of 20 amps capacity prior to equipment delivery.

3.5.6 SURFACING SAMPLES

After completion of the surfacing operations described in Section 3.5.4 and 3.5.5 samples were obtained from the surfacing applied during the timed surfacing operations. Twenty random samples, each approximately one foot square, were obtained from the approximately 10,500 sq ft of surface applied with the high rate equipment system. Likewise twenty random samples, each approximately one foot square, were obtained from the approximately 5,070 square foot of surface applied with the low rate equipment system.

Ten of each set of twenty surfacing samples were obtained from lapped or jointed areas. These samples were visually inspected for quality of joints, bonding of layers, resin penetration and quality of the surfacing as compared to the remaining ten random samples obtained from the non-lapped and non-jointed areas. Examination of the samples obtained from the lapped or jointed areas showed adequate resin penetration and overlap indicating that thorough bonding had occurred and that the strength at lapped and jointed areas was generally equal to that of the non-lapped or jointed surfaces.

From the twenty samples from the non-lapped or jointed areas (ten from each surface) specimens were obtained for strength testing. One specimen each for flexure, tension, and shear testing was obtained from each sample. The test methods used and the manner of calculating standard deviations has been previously described in Section 3.2. Table 38 summarizes the results obtained.

Table 38: STRENGTH TESTS RESULTS

High Rate Surfacing Test Results

Property	Strength (PSI)	Deviation (PSI)
Flexure	56,077	7,476
Tension	29,248	6,635
Shear	11,624	1,893

Low Rate Surfacing Test Results

Property	Strength (PSI)	Deviation (PSI)
Flexure	40,941	14,680
Tension	20,201	5,497
Shear	12,144	1,693

3.5.7 MOBILITY TESTING

Both the carrier vehicle (high rate system) and the trailer (low rate system) were subjected to a mobility and braking test. For these tests a tow vehicle was provided for the trailer. The tests required that the carrier vehicle and the trailer be driven over the types of terrain and speeds maintained as follows:

- o Paved highways or similar improved roads - 50 miles at 40 MPH
- o Graded gravel or similar unimproved roads - 25 miles at 20 MPH
- o Improved cross-country terrain - 10 miles at 5 MPH

The braking portion of the test required that each equipment item be subjected to not less than five sudden stops from a speed of 20 miles per hour. A stopping distance of thirty feet or less was specified for this test.

At the conclusion of the mobility and braking demonstration, both equipment items were inspected for evidence of misalignment, distortion or other damage caused by these tests.

3.5.7.1 Carrier Vehicle

The carrier vehicle was driven 76 miles on paved highway with speeds ranging from approximately 25 MPH on grades up to 55 MPH on level. An additional 26-1/2 miles was driven over a gravel road. Speeds ranged from that required to negotiate grades and sharp turns up to a maximum of 30 MPH on level. The carrier vehicle was driven a distance of ten miles over improved cross country terrain at an average speed of approximately eight miles per hour. During this portion of the test, apparently due to a faulty cotter pin installation, the structural pin connecting the upper end of the tilt actuator to the crane boom adapter fell out. This caused the actuator to swivel downward and, resting on hydraulic fittings, loosen them. After stopping, replacing and securing the pin, and tightening the hydraulic fittings, the test run was completed.

Overall performance throughout these tests was satisfactory and no adverse handling characteristics were noted.

For the braking demonstration a large paved area having a level, dry surface, free from loose materials was provided. Five sudden stops were made on pavement with stops occurring in less than thirty feet from twenty miles per hour.

At the completion of the mobility and braking test the vehicle was examined for damage. In addition, the fluid dispensing system engine and liquid pump drives were operated. No apparent damage was observed and all aspects of the test and equipment were satisfactory.

3.5.7.2 Trailer

The trailer was towed approximately eighty five miles on paved highways at speeds ranging from 40 to 60 miles per hour. An additional twenty-seven miles was accomplished on gravel roads at speeds up to 25 miles per hour. The trailer was towed over improved cross-country terrain for a distance of approximately 11 miles at speeds up to 14 MPH. The equipment performed satisfactorily with no adverse handling characteristics.

No evidence of damage was noted except that the outer casing on the left, front parking brake actuating cable had been chafed due to improper routing and an oversize clamp. This was corrected prior to delivery of the equipment.

For the braking tests five sudden stops were made from a speed of twenty miles per hour. All stops occurred in a distance of less than thirty feet.

Inspection of the trailer after the mobility and braking tests revealed no other evidence of damage to that previously noted. The fluid dispensing system engine and pump drives were operated and performance was satisfactory.

3.5.8 PRESSURE TESTS

Those elements of the high-rate and low-rate liquid systems that operated under positive pressure were pressure tested using applicable procedures of Section VIII of the ASME Boiler and Pressure Vessel Code. As stated in this code, water was used as the pressurizing medium and the test pressure was 1.5 times the maximum allowable working pressure. Each component and circuit of the high-rate and low-rate liquid systems that operates under positive pressure was tested to 1.5 times its respective maximum allowable working pressure.

The following general procedures and modifications to the systems were employed for this test. System check valves were bypassed or otherwise modified to allow pressurization of the system or circuit under test. Pump suction ports and spraybar openings were plugged. Pressure relief devices installed in the liquid lines were adjusted to the test pressures required for each element of the liquid systems. System pressure monitoring gages were replaced with laboratory type calibrated pressure gages.

Before applying the test pressures all joints and connections were inspected for tightness. The systems were then filled with water and all air bled from the lines. Pressure was then applied gradually until the test pressures were reached. Following the application of the test pressures, system pressures were reduced to the allowable working pressures and an inspection made of all joints and connections.

Prior to conducting the preliminary pressure test the liquid dispensing systems of both the high and low rate equipment were operated using methylene chloride.

3.5.8 PRESSURE TESTS (CONT)

This was accomplished in order to achieve cleaning and flushing of the plumbing lines. Subsequently, the systems were filled with water and pressure tests were conducted. Maximum operating pressures were achieved without leakage. However, when applying the required proof pressure factor of 1-1/2 times maximum operating pressure to the High Rate system, leakage occurred at the ferrule ends of three flexible hoses. These hoses (rated for 500 psi maximum operating pressure) were replaced with new hoses obtained from the supplier prior to final pressure testing. The Low Rate system successfully withstood the proof pressures without leakage. However, very slight leakage was observed, emanating from a shaft seal on the resin pump, before reaching proof pressure. This leak stopped after continued pressure application.

Final proof pressure testing was accomplished for both high and low rate fluid systems subsequent to surfacing operations and mobility testing. The test methods and procedures previously outlined were followed in conducting these final pressure tests.

For the high rate liquid dispensing system a proof pressure of 300 psi was applied upstream of the catalyst and promoter injection points. The resin system downstream from the catalyst injection point (as well as the catalyst system) to the spray bar shutoff valves was tested to 345 psi. Likewise the promoter system and resin promoter side from the injection point to the spray bar shutoff valves was tested to 398 psi. The remaining portion of the resin system between the spraybar shutoff valves and the spraybars was pressure tested to 120 psi. These pressures were 1.5 times the maximum operating pressures of the respective system components and all systems satisfactorily withstood the applied pressures.

Pressure testing of Low Rate liquid dispensing system was conducted in a manner similar to the High Rate systems pressure test. A proof pressure of 375 psi was applied to the resin system upstream of the catalyst and promoter injection points. All systems downstream of the catalyst and promoter injection points were tested to 675 psi pressure.

The systems satisfactorily withstood the pressures involved, with the exception of the flexible delivery hose which carries resin and promoter. Leakage occurred where the end ferrule is attached to the hose on the hose reel end of the assembly. Leakage still occurred when the pressure was reduced to the maximum operating point of 450 psi. These hose assemblies are rated by the supplier for 1,000 psi maximum operating pressure and 4,000 psi minimum burst pressure, well in excess of the 675 psi applied pressure. Since these hose assemblies had previously successfully withstood the proof pressure and no leakage was observed during surfacing operations, leakage was attributed to a gradual loosening at the end ferrule-hose assembly resulting from inadequate inspection by the supplier. As a result, a replacement hose was obtained from the supplier for delivery with the trailer. This replacement hose was certified by the supplier to have been hydrostatically tested to 1,800 psig for three minutes without leakage, damage or deformation. Certification data is contained in the Appendix.

3.5.9 OPERATIONAL REQUIREMENTS TESTING

The prime objective of these tests was to verify the reliability of both the high-rate and low-rate equipment liquid dispensing systems under simulated continuous surfacing operations. These tests were also performed to verify the capability of both equipment systems to dispense the required amounts of resin, catalyst, and promoter for the simulated condition. In addition it was required to verify that when dispensing polyester resins having a viscosity of 1600 centipoises, adequate resin sprayability, as indicated by the fan angle, was obtained at the spraybars (high-rate system) and the hand held spray bar (low-rate system).

To demonstrate the five and six hour continuous surfacing requirements for the high-rate and low-rate systems respectively, the actual cumulative time required to discharge the liquids during surfacing operations was considered the determining factor in development of the test. Therefore, actual pumping time and liquid delivery rates used for these tests were computed as follows and were based on the systems analysis presented in Section 3.3.2 of this document.

3.5.9.1 Test Requirements

For the high-rate system one 2-1/2 minute pass (refer to Section 3.3.2) requires two 6.5 ft wide x 250 ft long rolls of fiberglass and 1.2 lbs per sq ft total liquids. Therefore total liquid application rate is: $6.5 \times 250 \times 1.2 \times \frac{1}{2.5} =$ 780 lbs per minute.

Since total liquid is composed of 100 parts resin, 2.5 parts catalyst, and 1 part promoter, theoretical resin output is $\frac{100}{103.5} \times 780 = 754$ lbs per minute. Similarly theoretical promoter output $= \frac{1.0}{103.5} \times 780 = 7.5$ lbs per minute and theoretical catalyst output $= \frac{2.5}{103.5} \times 780 = 18.8$ lbs per minute.

This method however, assumes no loss of fluids to the underlying soil. To determine fluid loss to the underlying soil, nominal 2 lb per sq ft samples were constructed over loose, dry sand and silt sub-bases using a resin conditioned to a viscosity of 1600 centiposes (cps). All samples were subjected to two passes with a roller. Average resin gel time was approximately 20 minutes. The average weight of fluids lost to the underlying soil as determined by these tests was found to be 3.9% based on the weight of actual fluids applied. Based on the results of these laboratory tests, the required fluid delivery rates required for field applications using a 1600 cps viscosity resin were assumed to be 5% higher than the theoretical rates computed above. Therefore, fluid delivery rates used for this test were:

Resin	$754 \times 1.05 = 792$ lbs per minute
Promoter	$7.5 \times 1.05 = 7.9$ lbs per minute
Catalyst	$18.8 \times 1.05 = 19.8$ lbs per minute

3.5.9.1 Test Requirements (Cont)

Total materials required (Refer to Section 3.3.2) were:

Resin	= 69,552 lbs + 5% = 73,030 lbs
Promoter	= 696 lbs + 5% = 731 lbs
Catalyst	= 1,739 lbs + 5% = 1,826 lbs

Actual required pumping time for resin = $\frac{73,030}{792}$ = 93 minutes which was the same pumping time required for all liquids.

For the low rate system actual pumping time was computed similar to that for the high-rate system as follows:

One 6.5 ft wide x 50 ft long roll of fiberglass requires 0.6 lbs per sq ft total liquids in a two minute application time (Refer to Section 3.3.2) therefore, total liquid application rate is:

$6.5 \times 50 \times 0.6 \times \frac{1}{2} = 97.5$ lbs per minute and the theoretical resin application rate is

$\frac{100}{103.5} \times 97.5 = 94.2$ lbs per minute. Theoretical promoter and catalyst application rates are 0.94 and 2.36 lbs per minute, respectively.

As discussed above, actual fluid delivery rates required for field applications using a resin having a viscosity of 1600 cps was assumed 5% higher than the theoretical rates. Therefore, fluid delivery rates used for this test were:

Resin	94.2 x 1.05 = 98.9 lbs per min
Promoter	0.94 x 1.05 = 1.0 lbs per min
Catalyst	2.36 x 1.05 = 2.5 lbs per min

Total resin required (Refer to Section 3.3.2) was:

17,481 + 5% = 18,355 lbs and the actual required pumping time was:

$\frac{18,355}{98.9} = 186$ minutes

The following liquids were used for these tests and were continuously recirculated in order to reduce the quantities required.

Resin: PPG industries 5000 SC19-143 polyester resin formulated to have a viscosity of 1600 centipoise (CPS) at approximately 50°F was used for this test. This resin has a viscosity in excess of 1600 CPS during the manufacturing process and is subsequently diluted with styrene to the viscosities listed in Section 3.2. After completion of the operational tests the resin was diluted with styrene to obtain its normal viscosity, and was used in surfacing application checkout tests.

3.5.9.1 Test Requirements (Cont)

Promoter: Water was used in lieu of the dimethyl aniline promoter since the viscosities are similar and the hazards associated with the promoter were eliminated.

Catalyst: The catalyst material used was Noury Corporation's 40% benzoyl peroxide emulsion S-0046 green as no other substitute material was known that would be representative of the characteristics and behavior of this catalyst material under actual pumping conditions.

3.5.9.2 Test Procedures

Resin viscosity, occurring in the resin tote containers, was determined prior to the start of the operational tests for the high rate and low rate systems, respectively. A Brookfield viscometer was used to determine viscosity A viscosity of 1600 centipoise (CPS) was measured at a resin temperature of 56^{o}F for the high rate system test and a viscosity of 1616 CPS was measured at a resin temperature of 54^{o}F for the low rate system test. These temperatures were used as a guide in controlling resin viscosity during the tests. In general, temperature of the resin, as it was being continuously recirculated, was allowed to rise to approximately 60^{o}F before drawing resin from another tote container or stopping pumping operations in order to cool the resin such that the required viscosity was obtained. Temperatures of the catalyst and water (in lieu of the Dimethyl Aniline (DMA) promoter) were not controlled during the tests. Prior to continuously recirculating the liquids, resin sprayability and material output of the individual liquid systems were verified. Tables 39 and 40 present the data obtained during these tests for the high-rate and low-rate equipment liquid dispensing systems respectively.

Both equipment systems successfully met all requirements. Resin sprayability (as determined by visual observation) was satisfactory and liquid materials output was within allowable limits. Total system running time was 108 minutes for the high rate equipment and 187 minutes for the low rate equipment.

3.5.10 AIR TRANSPORTABILITY

The capability of the application equipment system items to be disassembled within one hour for air transport in C-130 type aircraft and reassembled for use within one hour after unloading was demonstrated. For the high rate equipment system the catalyst and promoter hoppers and the spraybar-glass support structure must be removed from the truck in order to meet the specified 25,000 pound weight limitation. The glass roller assembly must be disconnected from the tow tractor to meet the C-130 cargo envelope.

The actual times required for the above tasks were as follows:

> Removal of the catalyst and promoter hoppers from the truck and disassemble the spraybar-glass support structure from the vertical mast required three men twenty minutes. One of the three men operated a forklift as required during this demonstration.

Table 39: OPERATIONAL REQUIREMENTS TEST DATA – HIGH RATE SYSTEM

Liquid Output

Resin – 764 Lbs Per Minute (Allowable 792 ± 40 Lbs Per Minute)

Catalyst – 20.1 Lbs Per Minute (Allowable 19.8 ± 1.0 Lbs Per Minute)
Pump Set at 21% Output.

Water – 8.5 Lbs Per Minute (Allowable 8.3 ± 0.4 Lbs Per Minute)
Pump Set at 58% Output.

Correcting for the Specific Gravity of DMA (0.96 as Compared to 1.0 for Water) the Corresponding Output for DMA Would be 8.5 x 0.96 ≚ 8.2 Lbs Per Minute as Compared to an Allowable of 7.9 ± 0.4 Lbs Per Minute.

Liquid System Running Time

Resin Tote	Resin Temperature (°F) Start	End	Time (Minutes)	Cumulative Time (Minutes)
Left	56	60	25	25
Right	56	62	11	36
Left	56	60	22.9	58.9
Right	56	60	9.1	68
Left	53	60	12	80
Right	57	63	13	93
Left	56	Not Recorded	15	108

System Data

Engine RPM – 1800

Liquid System Pressures

Resin – Pressure Averaged 167 psi and 143 psi at Start and End of Each Pumping Increment, Respectively.

Catalyst – 90 to 210 psi

Promoter – 160 to 200 psi

Catalyst Temperature – 60°F at Start of Test, 71.5°F at End of Test.

Water Temperature – 60°F at Start of Test, 64°F at End of Test.

Table 40: OPERATIONAL REQUIREMENTS TEST DATA – LOW RATE SYSTEM

Liquid Output

Resin – 99 Lbs Per Minute (Allowable 98.9 ± 4.94 Lbs Per Minute)

Catalyst – 2.51 Lbs Per Minute (Allowable 2.5 ± 0.12 Lbs Per Minute) Pump Set at 60% Output.

Water – 1.02 Lbs Per Minute (Allowable 1.04 ± 0.5 Lbs Per Minute) Pump Set at 29% Output.

Correcting for the Specific Gravity of DMA (0.96 as Compared to 1.0 for Water) the Corresponding Output for DMA Would be 1.02 x 0.96 ≚ 0.98 Lbs Per minute as Compared to an Allowable of 1.0 ± 0.05 Lbs Per Minute.

Liquid System Running Time

Increment	Resin Temperature (°F) Start	Resin Temperature (°F) End	Running Time (Minutes)	Cumulative Time (Minutes)
1	54	58	93	93
2	59*	58*	30	123
3	54	60	64	187

System Data

Resin Pump RPM – 550-560

Liquid System Pressures:

- Resin – 160 to 138 psi
- Catalyst – 90 to 110 psi
- Promoter – 165 to 175 psi

Catalyst Temperature – 60°F at Start of Test, 66°F at End of Test.

Water Temperature – Not Recorded

* Added Cooling Provided During Run.

3.5.10 AIR TRANSPORTABILITY (CONT)

Installation of the catalyst and promoter hoppers and assembly of the spraybar-glass support structure to the vertical mast was accomplished by the above three men in twenty minutes.

Disconnection of the glass roller assembly from the tow tractor was accomplished by two men in four minutes. Connection also was accomplished by two men in four minutes.

The only items requiring disassembly f · air shipment of the trailer are the catalyst and promoter drum support structures which are bolted to the vertical frame members of their respective hoppers. Each drum support structure requires the removal and subsequent reinstallation of thirty-two bolts. Actual demonstration of these tasks for the trailer was not accomplished. It was considered through visual observation that these tasks could be accomplished within the one hour time period allowed.

3.5.11 DIMENSIONS AND WEIGHTS

Overall dimensions and weights were determined for the completely assembled equipment items and their respective component parts. Three methods of obtaining the required dimension and weight data were used. Actual measured and observed data for major equipment items such as the high-rate equipment system carrier vehicle, manufacturer's data for items such as engines and pumps, etc., and calculated data from fabrication drawings for items such as operator control stands. Tables 41 and 42 show the items for which dimensional and weight data were obtained and the method of obtaining this data for the high-rate and low-rate equipment systems respectively.

3.6 Operations and Maintenance Manuals

As part of this program operations and maintenance instruction manuals were prepared for both the high-rate and low-rate equipment systems. Preparation of these manuals (Reference 18 and 19) was accomplished such that all portions of the systems were accounted for in order to be suitable for use by military personnel. The manuals include as a minimum the following:

- Description and mixing instructions for surfacing materials
- Method of surfacing material application
- Description of the complete system
- Operating procedures
- Control methods for dispensing surfacing materials
- Schematics and wiring diagrams
- Trouble shooting procedures and repair procedures
- Maintenance instructions
- Recommended cleaning, storage and transportation procedures
- Recommended spare parts lists with prices
- Necessary contractor drawings, vendor drawings, to facilitate maintenance, repair, disassembly and assembly of the system

Table 41 : DIMENSION AND WEIGHT DATA – HIGH-RATE EQUIPMENT SYSTEM

Equipment System Item	Actual Measured/ Observed Data *	Manufacturer's Data *	Calculated *
Carrier Vehicle (As received from Manufacturer)	13,160 lb. 96 x 99 x 359		
Carrier Vehicle (Assembled)	26,300 lb 108 x 119 x 425		
Engine		645 lb. 25 x 36 x 43	
Crane		2,255 lb. 38 x 57 x 218	
Control Stand			223 lb. 18 x 39 x 36
Resin Pump		475 lb. 13 x 17 x 32	
Catalyst Pump		675 lb. 14 x 18 x 59	
Promoter Pump		150 lb. 9 x 14 x 37	
Solvent Pump		6 lb. 4 x 3 x 8	
Catalyst Hopper			445 lb. 30 x 63 x 41
Promoter Hopper			332 lb. 24 x 56 x 41
Glass & Spray Bar Assembly	612 Lb. 112 x 25 x 83		
Tractor		3,450 lb. 78 x 96 x 132	
Roller Assembly	1,350 lb. 24 x 72 x 192		
Wash Tank	220 lb 22 x 18 x 131		
Special Tools	202 lb. 18 x 6 x 105		

* All dimensions in inches, width x height x length.

Table 42: DIMENSION AND WEIGHT DATA – LOW-RATE EQUIPMENT SYSTEM

Equipment System Item	Actual Measured/ Observed Data *	Manufacturer's Data *	Calculated *
Trailer (as received from supplier)	6,300 lb. 96 x 72 x 280		
Trailer	10,030 lb. 96 x 119 x 280		
Removable Pumping Unit	2,200 lb. 96 x 101 x 84		
Engine		135 lb. 21 x 22 x 20	
Resin Pump		40 lb. 8 x 6 x 14	
Catalyst/Promoter Pump		165 lb. 15 x 18 x 18	
Solvent Pump		6 lb. 3 x 4 x 8	
Control Stand			118 lb. 18 x 39 x 19
Hose Reel		140 lb. 32 x 33 x 34	
Spray Guns	22 lb. 18 x 8 x 86		
Fiberglass Dispensing Yoke	34 lb. 36 x 16 x 65		
Resin Roller	14 lb. 20 x 5 x 65		
Special Tools	37 lb. 18 x 8 x 44		

* All dimensions in inches, width x height x length.

Note: See Table 41 for Catalyst and Promoter Hopper Dimensions and Weight.

3.7 Drawings and Specifications

As part of the overall program, drawings and specification conforming to Category E, Form 2 of Military Specification MIL-D-1000 were prepared. These were in addition to the normal layout-design drawings and specifications required for equipment system design and fabrication. In addition, specifications for surfacing materials were required as part of the overall program documentation.

The MIL-D-1000 drawings and specifications were prepared on mylar and good drawing practices emphasized. Drawings 180-12309 and 180-12362 show the high rate and low rate surfacing systems respectively.

Extensive discussion on the properties, characteristics, hazardous properties, effects on ecology, and storage recommendations for the surfacing materials has been presented in Sections 3.2 and 3.3 of this document. Mention was made of packaging methods and techniques; however, as the program progressed certain modifications to these suggested methods were required in order to conform to the final design of the equipment systems. The packaging methods selected, as well as a suggested method for packaging the fiberglass reinforcement are discussed below.

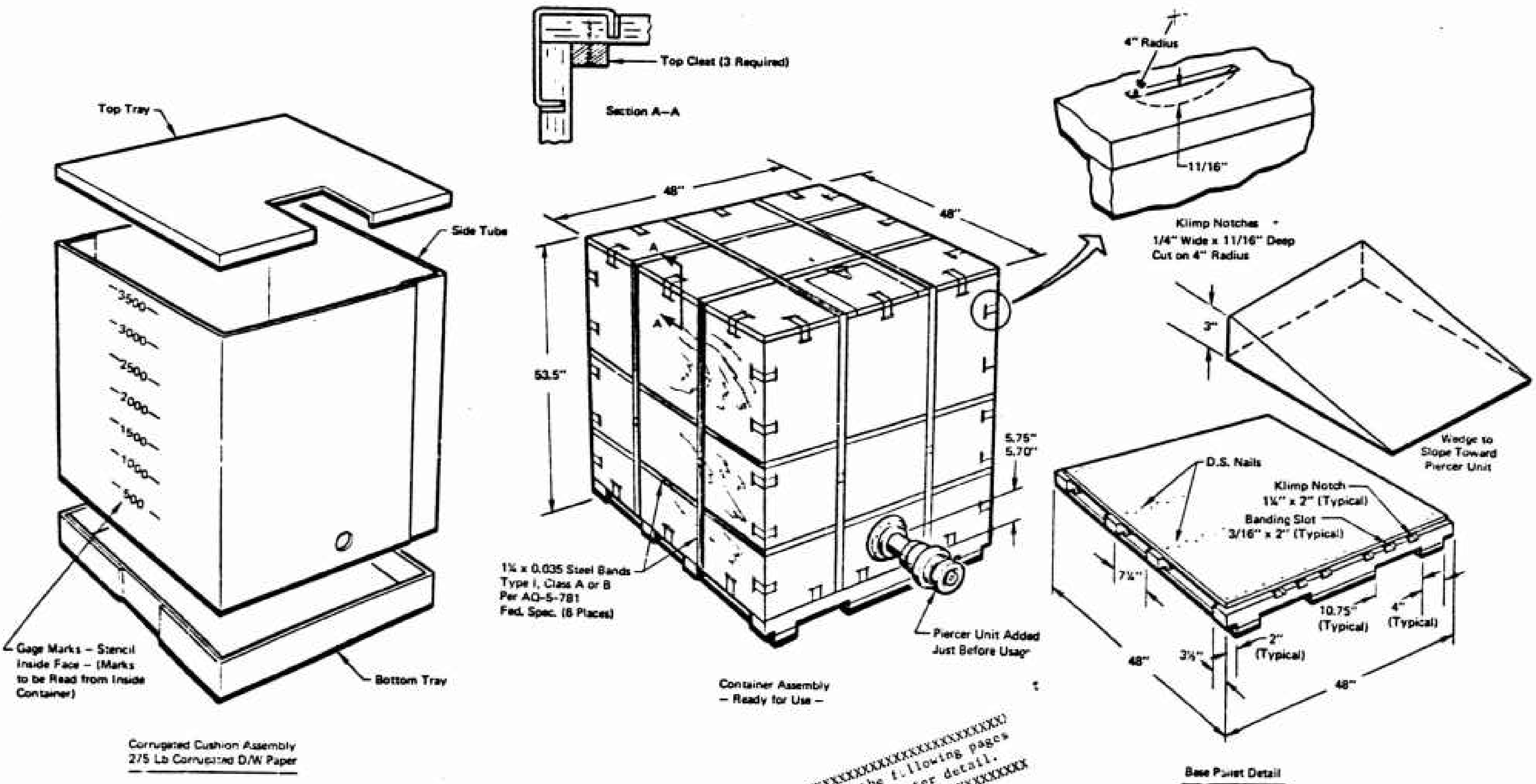
- o Polyester Resin - Plywood containers similar to those previously used in the On-Fast program. Capacity enlarged to approximately 350 gallons per container. Container has 48 inch by 48 inch planform and modified resin connector to prevent leakage. Sloping bottom provided for less wastage of material. The container is illustrated in Figure 115. Resin is contained within plastic liners (not shown) that are cushioned by the corrugated paper. Three 4 mil plastic bags are used to make up the liner.

- o Promoter Dimethyl Aniline - Package in standard 30 gallon containers 3/4 inch vent and 2 inch openings on container sides required for interface with on-board promoter hopper. Figure 116 illustrates the promoter container.

- o Catalyst S-0046 Green (40% Active Benzoyl Peroxide Emulsion): Package in standard 55 gallon open top containers as material may require mixing prior to use. Figure 117 illustrates the catalyst container. Side openings required for interface with on-board catalyst hopper.

- o Solvent Methylene Chloride: Package in standard 55 gallon containers as illustrated in Figure 118. Additional 3/4 inch openings required for venting when containers are used as on-board solvent containers.

- o Fiberglass Reinforcement: Basic system material is considered 40 oz per square yard woven roving with 2 oz per square foot chemically bonded chopped strand mat. Basic width is considered to be 6.5 feet. Figure 119 shows a suggested method for fiberglass packaging.



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for greater detail.
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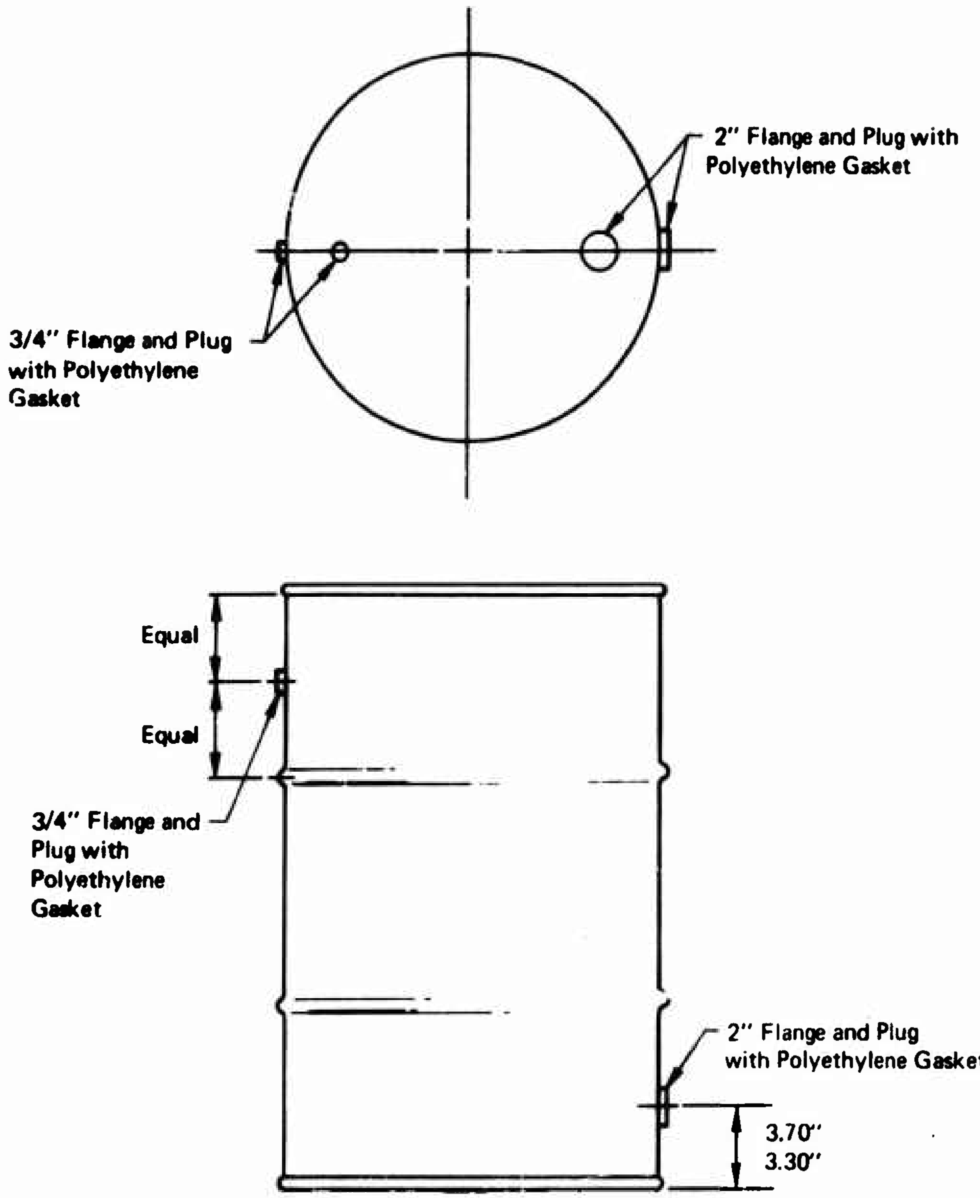
Figure 115: RESIN CONTAINER

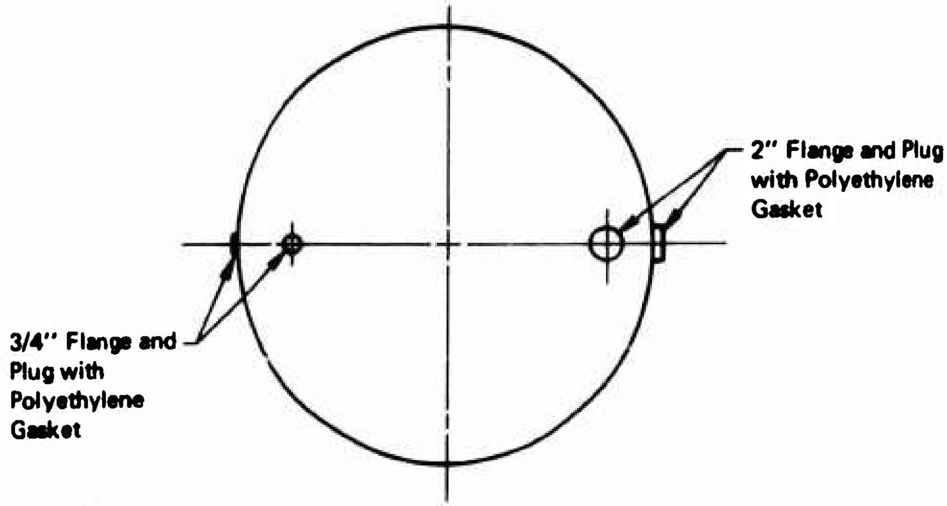


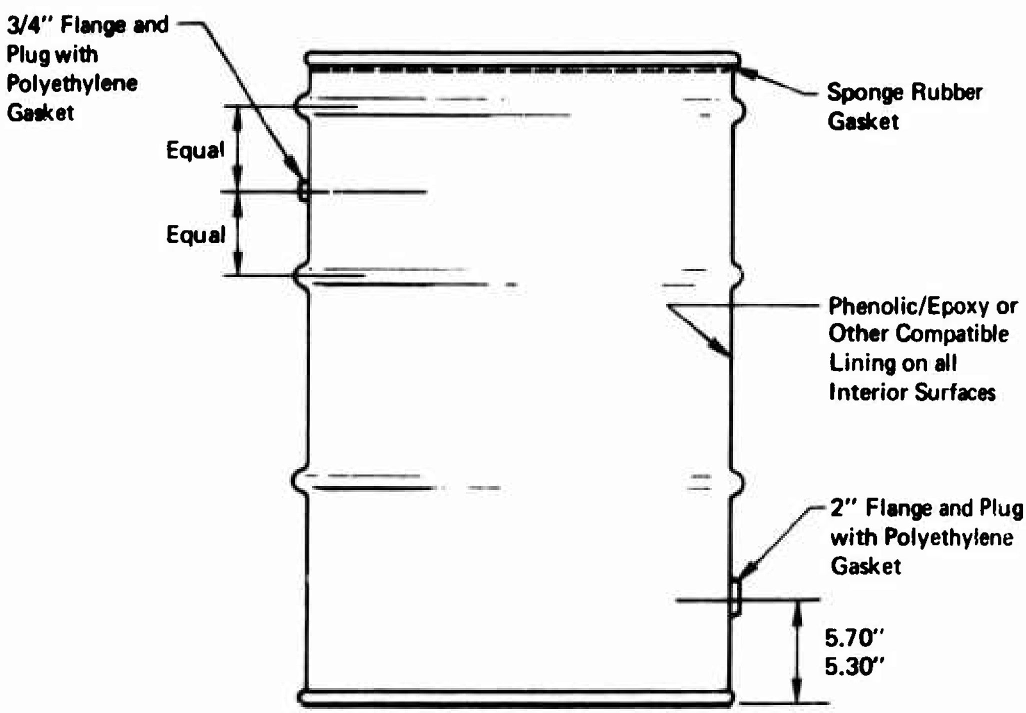
30 Gallon Drum per Fed. Sped. PPP-D-706

Type I – ICC-17E Straight Side Cylindrical Drum, Double Seamed Chimes, Tight Head.

Note: Print All Exterior Surfaces Yellow.

Figure 116 : PROMOTER CONTAINER



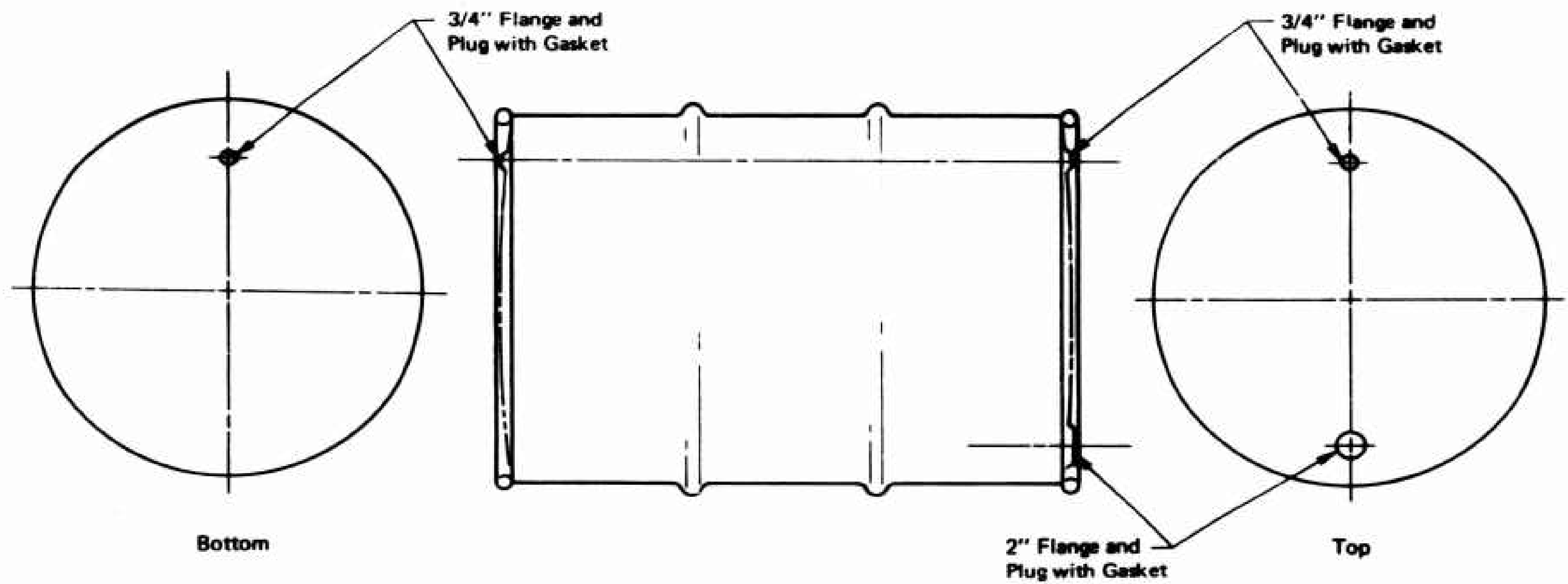


55-Gallon Drum Per Fed. Spec. PPP-D-729

Type III Rule 40 or
Type IV ICC-17H Straight Side Cylindrical, Full Removable Cover
Provided with Removable Bolted Type Locking Ring.

Note: All Exterior Drum Surfaces to be Painted Green.

Figure 117 : CATALYST CONTAINER



Note: Gasket Material to be Compatible with Methylene Chloride

55-Gallon Steel Drum per Fed. Spec. PPP-D-729

Type I – ICC 5B – Straight Side, Cylindrical Drum; Double Seamed Chime. with Chime Reinforcement, or

Type II – ICC 17E – Straight side, Cylindrical Drum; Double Seamed, Chime, without Chime Reinforcement.

Note: Paint all Exterior Surfaces White

Figure 118: SOLVENT CONTAINER

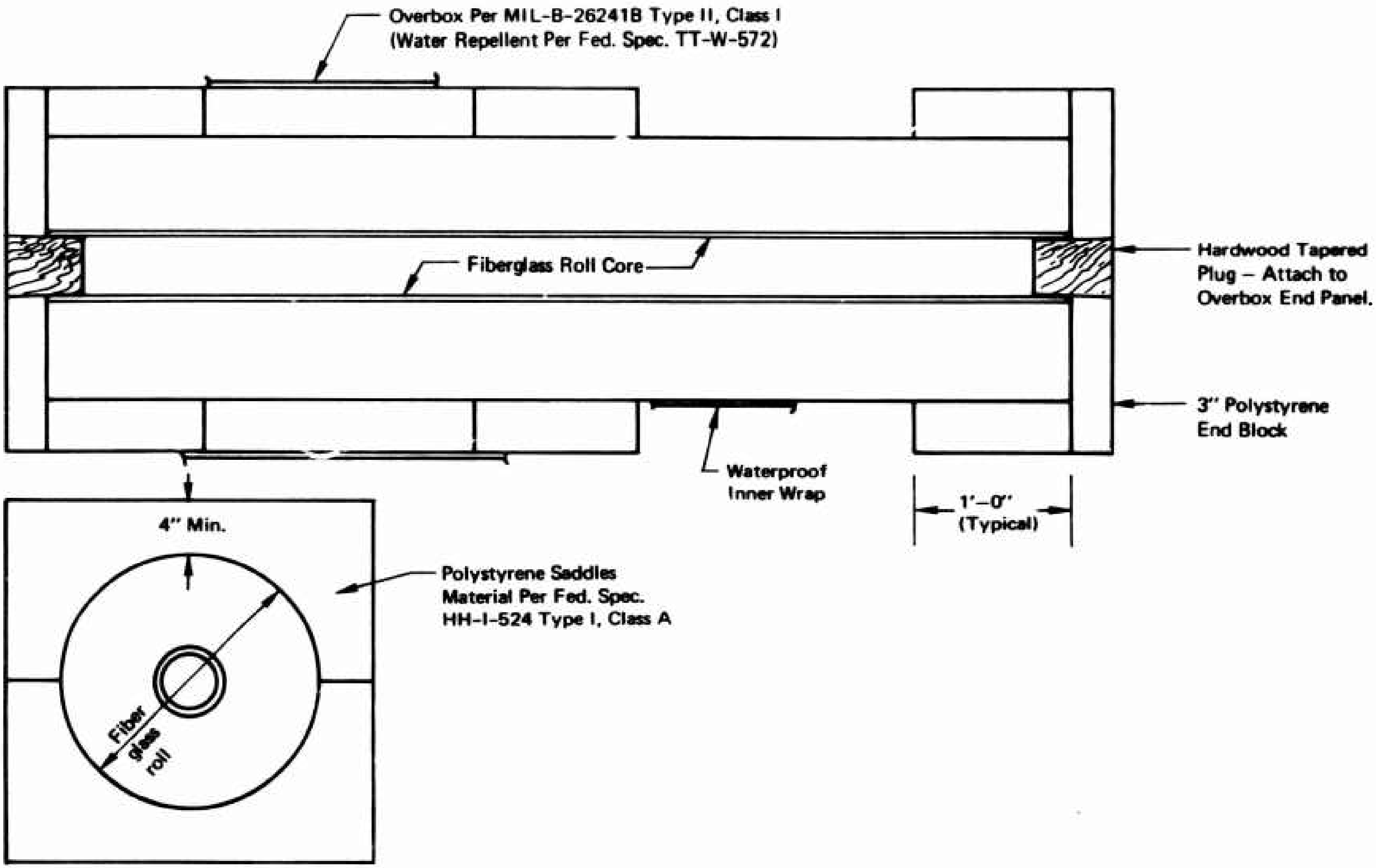


Figure 119 : FIBERGLASS PACKAGING

3.7 Drawings and Specifications (Cont)

All materials shipped to adverse weather/combat areas require Level A military pack in accordance with MIL-STD-129. All steel drums require a paint system specifically to withstand corrosive effects of weather, and weatherproof, non-corrosive, non-degradable labels are required for absolute identification of contents.

The surfacing materials used during the program (with the exception of the solvent) may be obtained from their respective manufacturers under the following designations:

1) Polyester Resin 26540 - Hooker Chemical, Durez Div.

2) Polyester Resin RS 5000 SC19-143 - PPG Industries

3) Laminac 410 promoter (100% Active Dimethyl Aniline) - American Cyanamid

4) Catalyst S-0046 Green (40% benzoyl peroxide emulsion) - Noury Chemical Corporation

5) Fabmat C-4020 Fiberglass Reinforcement (40 oz/sq yd woven roving with 18 oz/sq yd chopped strand matting) - Fiberglass IND's

The methylene chloride solvent is defined by MIL-D-6998. It is commercially available and may be procured locally. It should be noted that the RS 5000 SC19-143 code number assigned to PPG IND's polyester resin designates an experimental material. For production quantity runs it has been assigned code number RS50129. It may be obtained under either the experimental or production code number.

Manufacturer's certification as to material along with suitable labeling of materials should be required in order to adequately verify materials received for field usage. Source inspection for the mechanical and physical properties of the materials previously discussed in Sections 3.2 and 3.3 may also be considered as a means of suitably identifying and verifying materials.

In addition to the above, applicable provisions of MIL-M-43248 (MR) and MIL-D-2035 may be cited when ordering fiberglass reinforcement and Dimethyl Aniline respectively.

4.0 CONCLUSIONS, RECOMMENDATIONS AND FOLLOW-ON ACTIVITIES

4.1 Conclusions

Surfacing Materials and Packaging: The surfacing materials selected have demonstrated satisfactory performance. These materials produce a surface of high strength, permit controlled curing under a wide range of field conditions, and are suitable for a wide variety of uses. The woven roving reinforcement has inherent tendencies to wrinkle when emplaced on other than flat surfaces or when deviations from straight roll-out occur. This is not considered serious for most uses but does suggest investigation of other types of reinforcement. The emulsified benzoyl peroxide is very satisfactory as a curing agent but is predisposed to complicate dispensing equipment and increase the system cleaning burden. The methylene chloride solvent is very effective as a cleaning agent and the nonflammable properties are a necessity for such usage. The surfacing materials packaging concept is well suited for military operational usage and commensurate with maintaining a high rate of surfacing. However, it is probable that the resin container could be simplified particularly with respect to the plastic inner liners.

Operational Usage: It is considered that the prototype advanced surfacing systems are suitable for field usage, including capability to achieve the required surfacing rates, as indicated by the operational usage studies and verified by the surfacing tests and demonstrations. Personnel tasks, surfacing equipment operations, and ancillary equipment operations during tests and demonstrations were based directly on the operational usage studies and established their general validity.

Prototype High Rate Application Equipment: The high rate truck mounted application equipment exhibited satisfactory design and performance characteristics. The truck has the required mobility and speed range to accomplish surfacing and maintain highway speed. The crane provides adequate capability to surface to the left, the rear, or to the right of the truck. The liquid dispensing system exhibited consistent, reliable performance. The surface rolling equipment proved to be very effective. The roller cleaning equipment was also very effective. Cleaning of the application equipment would be improved by the use of throw away plastic sleeves on the fiberglass guide rollers.

Prototype Low Rate Application Equipment: The trailer mounted application equipment exhibited satisfactory design and performance characteristics as regards surfacing and mobility. However, the parking brakes are not per MIL-M-008090E requirements and capability to meet these requirements in the future is questionable. The liquid dispensing system exhibited consistent, reliable performance. Performance of the fiberglass dispensing equipment was also satisfactory. The manual surfacing rollers, while adequate for small or uneven areas, are not adapted to rolling large flat areas and are not as effective for this as the high rate equipment. Larger rolling equipment possibly towed by a vehicle would probably be more effective. The cleaning equipment proved satisfactory. However, larger rolling equipment would require a larger cleaning trough.

4.1 Conclusions (Cont)

Systems Tests and Demonstrations: All specified systems tests and demonstrations were successfully performed indicating adequacy of the systems for operational usage and indicating the desirability of a follow-on production program based on the prototype systems. The roller equipment structural failure, the sprocket chain separation, and the flexible hose leakage, in view of reasons for occurring and corrective measures taken, are not considered to reflect on overall systems capability.

4.2 Recommendations

The following recommendations are submitted.

Investigation should be made relative to availability or development of fiberglass reinforcement matting which has reduced or minimum tendencies to wrinkle.

Development effort should continue on producing a low viscosity liquid catalyst which has capability to effect resin cure over a wide environmental range. Such a catalyst would reduce dispensing system complexity and reduce cleaning burden.

Investigation should be made relative to simplifying the resin container. One approach would be to replace the three thin plastic liners with a single heavy gage, semi-rigid liner, with integral shut off valve. Figure 120 shows a comparable concept developed by Seattle Box Co.

The use of throw-away plastic sleeves on the fiberglass guide rolls, as a means of simplifying cleaning, should be investigated.

Military specification MIL-M-008090F should be reviewed relative to applicability to large trailers and consistency with current requirements of agencies such as the I.C.C. and D.O.T. Applicable revisions and updating should be accomplished.

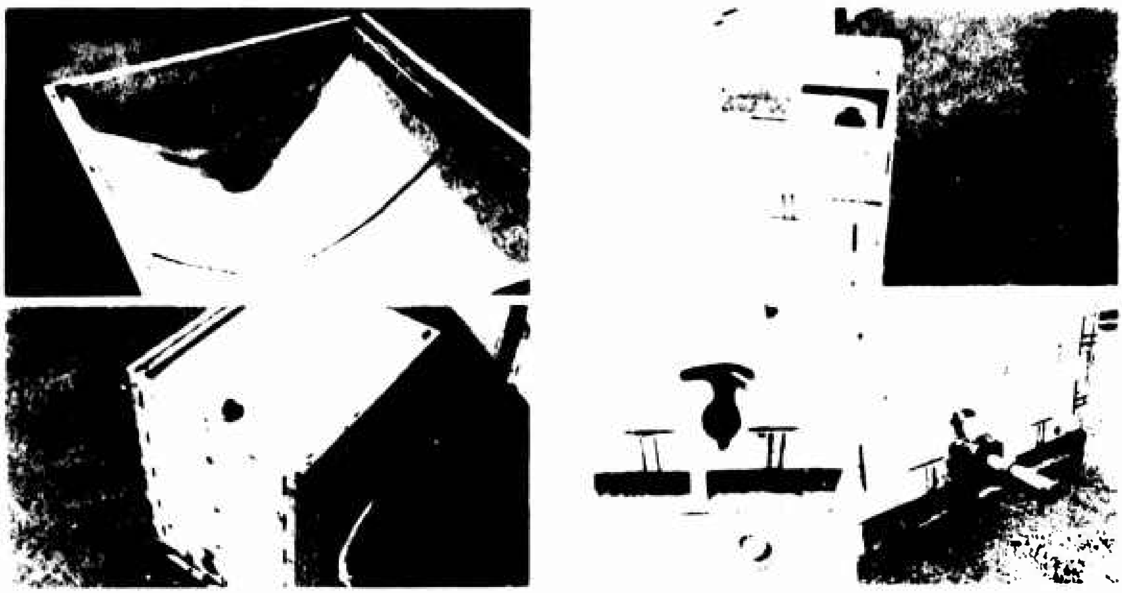
A larger surfacing roller for use on large areas should be developed and evaluated for the low rate system. Matching roller cleaning equipment should also be developed.

An advanced surfacing systems production program, based on the prototype systems and considering the foregoing recommendations, should be implemented as soon as feasible.

4.3 Follow-On Activities

In addition to the foregoing recommendations it is considered that the following activities should be undertaken.

A training program should be implemented to train military personnel in operation and maintenance of the prototype advanced surfacing systems prior to usage by military personnel only. This training program is considered particularly necessary for the high rate system.



LINER DATA

Material: .010 or .020 Closed Cell PVC

Size:

L	W	H
48	48	53
48	48	48
48	44	53
48	44	44

Figure 120: MODIFIED RESIN CONTAINER LINER

4.3 Follow-On Activities (Cont)

In addition to further field testing of the prototype advanced surfacing systems with the surfacing materials developed under contract N62399-71-C-0016, testing should be accomplished as soon as possible using the material system being developed for the Air Force by the Dow Chemical Company.

Investigations should be made and appropriate development implemented toward providing adapter kits for the high rate application equipment resulting in increased versatility. Such kits could include providing capability to dispense chopped roving for use on curved or irregular surfaces or special attachments for surfacing areas such as ditches or banks.

5.0 REFERENCES

1) Development and Fabrication of Prototype Advanced Surfacing Systems for Military Use on Soils, Contract N62399-71-C-0016, Naval Civil Engineering Laboratory, Port Hueneme, California, 71 June 01

2) Advanced Surfacing Systems, Material Selection and Verification, Boeing Document D180-12997-1, Revision A, July 1971

3) Advanced Surfacing Systems, Operational Usage Study, Boeing Document D180-12989-1, Revision B, July 1971

4) Preliminary Design Data - Advanced Surfacing Systems, Boeing Document D180-14170-1, Revision A, Sept. 1971

5) Preliminary Design Data - Advanced Surfacing Systems, Boeing Document D180-14261-1, Nov. 1971

6) Test Plan - Advanced Surfacing Systems, Boeing Document D180-14507-1, Revision A, Feb. 1972

7) On-Fast System Field Test, Boeing Document D162-10305-1, Sept. 1970

8) Proposed Military Specification, Resin, Polyester Wet-Lay-Up, Boeing Document D6-53532, Feb. 1968

9) Rapid Site Preparation for VTOL Aircraft - A Program Summary, R. D. Sherril, H. R. Bankhead, and Major A. L. Telford; Air Force Aero Propulsion Laboratory, Wright-Patterson A.F.B., Ohio

10) Rapid Site Preparation Techniques for VTOL Aircraft, AFAPL-TR-66-116 Part III, Vol. II, July 1969

11) Processing of Motor Vehicles for Storage and Shipment, TO 36-1-5

12) Food Additives Regulations, Subpart F, Food Additives Resulting from Contact with Containers or Equipment and Food Additives Otherwise Affecting Food, Amendments published in Federal Register, January 11, 1966; 31 F.R. 290

13) Dangerous Properties of Industrial Materials, by N. Irving Sax

14) Chemical Safety Data Sheet SD-81 for Benzoyl Peroxide, Adopted 1960, Manufacturing Chemists Association

5.0 REFERENCES (CONT)

15) Title 29 CFR, Part 1910 - Occupational Safety and Health Standards, May 29, 1971 (as amended August 13, 1971)

16) Chemical Safety Data Sheet SD-17, Properties and Essential Information for Safe Handling and Use of Aniline, Revised 1963, Manufacturing Chemists Association

17) Flow of Fluids Through Valves, Fittings, and Pipe, Technical Paper No. 410, Crane Co., Chicago, Ill., 1969

18) Advanced Surfacing System, High Rate System Operation and Maintenance Instructions, Boeing Document D180-14834-1, Dec. 1972

19) Advanced Surfacing System, Low Rate System Operation and Maintenance Instructions, Boeing Document D180-14835-1, Dec. 1972

APPENDIX A

MATERIALS DATA

During the materials verification portion of the program, data on the mechanical and physical properties of the 26540 and 5000 SC19-143 resin was requested from the respective manufacturers. Figures A-1 and A-2 are the data submitted for the 26540 and 5000 SC19-143 resin, respectively.

hooker durez DIVISION

NORTH TONAWANDA, NEW YORK 14120, PHONE (716) 693-1860

June 30, 1971

Mr. Bob MacIntosh
Orgn. Ma 8440, MS 2382
Boeing Company
Military Airforce systems Div.
Box 3955
Seattle, Washington 98124

Dear Mr MacIntosh

At your request, we have determined the following information on Hetron 26540:

Property	Value
Tensile Elongation at break	
1/8" casting	1.82%
1/16" Casting	1.99%
Heat Distortion Temperature (264 psi)	66.5°C
% H_2O absorption 24 hr room temp	
1/8" laminate	0.08%
1/16" laminate	0.12%
% H_2O absorption 24 hr @ 100°C	
1/16" laminate	0.19%
1/8" laminate	0.12%

For the Taber abrasion resistance, we have enclosed a graph showing the abrasion with a CS-17 wheel with 1000 gm weights.

We do not have any information concerning Mil-H-5606 Hydrolic Oil or IPA (T-I 735) resistance. However, we feel that these materials are not a threat to degrading of this polyester

Figure A-1: MANUFACTURER'S DATA — RESIN 26540 (Sheet 1 of 3)

hooker

Boeing Co.
June 30, 1971
Page 2

If there are any questions on the above information, please do not hesitate to call.

Yours truly

W.J. Purosky /kessit

W. J. Purosky
Polyester
Technical Service

mb

Enc.

Figure A-1 : MANUFACTURER'S DATA – RESIN 26540 (Sheet 2 of 3)

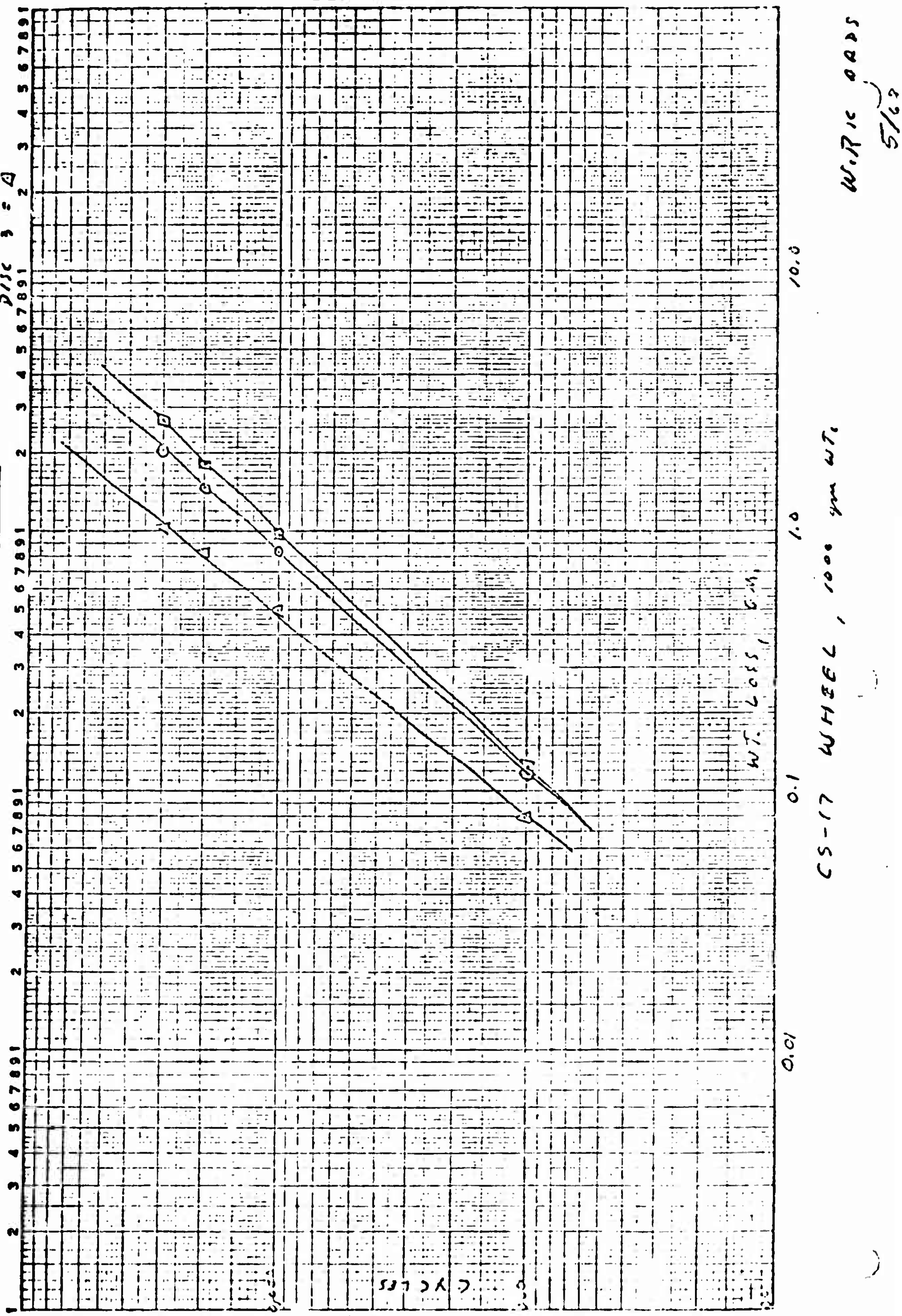


Figure A-1: MANUFACTURER'S DATA – RESIN 26540 *(Sheet 3 of 3)*

PPG INDUSTRIES

PPG INDUSTRIES, INC./ROOM 100/500 OFFICE CENTER BLDG./FORT WASHINGTON, PA 19034/AREA 215/643-4720

Resin Products Sales
Coatings and Resins Division

June 18, 1971

Mr. Robert MacIntosh
Boeing Company
Organization M-8441
Mail Stop 2382
Military Airplane Systems Division
Seattle, Washington 98124

Dear Bob:

Confirming our conversation I am enclosing the test data obtained on SELECTRON 5000-SC19-143.

I trust this information will be helpful, and if we can be of any further assistance do not hesitate to call.

Sincerely,

Charles G. Brown
Regional Manager
Resin Products Sales

CGB:el

Encl.

Figure A-2: MANUFACTURER'S DATA – RESIN 5000 SC 19-143 (Sheet 1 of 2)

Physical Properties - SELECTRON 5000 SC19-143

	Casting
Flexural Strength, psi	11,023
Flexural Modulus, $X10^5$	5.71
Tensile Strength, psi	5,290
Tensile Modulus, $X10^5$	5.21
Elongation in Tension, %	1.10
Heat Distortion, 264 psi, ^oC.	97
Izod Impact Strength, Ft. lbs./in. notch	0.374
Compressive Strength	21,725
Barcol Hardness	47-52
Water Absorption, 24 hr. immersion, %	0.158
Hydraulic Fluid, %	0.2
Iso Propyl Alcohol, %	1.2
Taber Abrasion Resistance CS-17 Wheel	
100 cycles - 50 mgl/1000	
500 cycles - 50 mgl/1000	

Figure A-2: MANUFACTURER'S DATA – RESIN 5000 SC 19-143 (Sheet 2 of 2)

APPENDIX B

EQUIPMENT CAPABILITY CERTIFICATION

The equipment item certification data received from suppliers is contained in Figures B-1 and B-2. Since all tests during the program were conducted under ambient conditions, proof of equipment capability to operate at from minus 25°F to plus 125°F was required. This data is presented in Figure B-3.

titeflex A DIVISION OF ATLAS CORPORATION
603 Hendee Street, Springfield, Massachusetts 01109
Phone 413-739-5631 · TWX 413-781-2191 · TELEX 95-5434

September 15, 1972

TO: Boeing Company

PO: 99683

QTY: 1 pc

CERTIFICATION

It is hereby certified that the assembly mentioned above, in reference to Goodall Rubber Company's purchase number, was 100% pressure tested hydrostatically at 1800 PSIG with H_2O for a period of three (3) minutes without leakage, damage or deformation.

Robert W. Wilder
TF, QC, General Foreman

RWW/pd

Figure B-1 : MANUFACTURER'S CERTIFICATION – RESIN DELIVERY HOSE, LOW RATE SYSTEM

A. B. CHANCE CO.

PITMAN MFG. CO. DIVISION

ENGINEERING TEST REPORT

REPORT NO: 72-1	
TO: Bill Rainwater (6) Wes Poyner Jack Stilwell	PROJECT NO: U-11142
	ENGINEER: Bryce Robinson
TITLE: Testing of Special PC-55 Crane for Boeing	PAGES: 1
TEST DATE: 3-28-72 / REPORT DATE: 4-13-72	APPROVED:

OBJECTIVE OF TEST:

1. Test assembly for proper functioning.
2. Check pressure relief setting of the control valve.
3. Test lifting capacity of crane at a radius of 12'6" with booms flat out.

TEST PROCEDURE:

1. Crane was mounted on the test pedestal.
2. Hydraulic source was the hydraulic test stand with the output flow set at 5 gpm.
3. A 12 VDC wet cell battery was used to actuate the solenoid valves.
4. All functions were operated.
5. A 2500 lb. weight was used to test the lifting ability of the crane.

RESULTS:

1. All functions of the crane worked properly.
2. The main pressure relief valve setting was 2500 psi.
3. The swing circuit pressure relief valve was 2500 psi.
4. The crane lifted 2500 lbs. at a radius of 12'6" and the booms flat out.

CONCLUSIONS:

1. All functions operate as designed.
2. The swing circuit relief setting was 2500 psi. Purchase description for valve specified 2000 psi. This will not affect unit operation. Decision was made to ship as is rather than hold shipment for replacement springs.
3. The crane has the specified lifting capacity.

RECOMMENDATIONS:

1. Order new 2000 psi pressure relief springs for the swing circuit.

Figure B-2: MANUFACTURER'S CERTIFICATION – PC 55 CRANE

HIGH RATE SYSTEM

Item	Operating Temperature – Verification Data
• Engine with Clutch Reduction Unit, Wisconsin VG-4D and Twin Disc Clutch Reduction Unit	Wisconsin Letter
• Catalyst Pump, Milton Roy MR 1-68A-140 SM	Catalog Data, -20°F to +125°F. Verbal confirmation from Manufacturer that pump range can be extended to -25°F.
• Promoter Pump, Milton Roy MR 1-911-92 SM	Same as Catalyst Pump
• Resin Pump, Viking I Q124	Pump, -60°F to +650°F, Catalog Data. Reducer, 0°F to 150°F. Catalog Data. Mfgr. verbally confirms satisfactory operation to -25°F using SAE 10 W lubricant.
• Miter Gear Box, Morse 6M	+20°F & above – SAE 90 Gear Oil. 0°F to +20°F · SAE 80 Gear Oil -25°F – 0, Mobil Compound AA or Texaco Meropa No. 2 (Catalog data and verbal recommendation from Russ Morse of Morse Denver Plant)
• Power Take-off Spicer S32D-A16 and Power Divider, Watson WD-3	Distributor recommends truck transmission oil. Fuller Transmission Lube Data recommends MIL-L-2105 for below -10°F
• Crane Rotation Gear Box	Mfgr. (Pitman) recommends MIL-L-2105B for low temp. operation to -25°F.
• Hydraulic System	Mfgr. (Pitman) confirms satisfactory operation to -25°F and recommends MIL-H-5606A oil for low temp. operation (system has MIL-H-5606A oil).
• Solvent Pump, Viking F432	-60°F to +450°F, Catalog Data.
• Solvent Hose, Parker H510-6	-40°F to +225°F, Catalog Data.
• Ball Valves, Worcester 600	-50°F to +450°F, Catalog Data.
• Ball Valves, James Bury A22TT and A36TT.	Mfgr. verbally confirms satisfactory operation to -25°F (materials & construction nearly identical to Worcester Ball Valves).
• Resistoflex Hoses	-65°F to +275°F, Catalog Data.
• Engine and Reduction Unit (Wisconsin AENLD)	-25°F to +125°F per Wisconsin Letter
• Resin Pump, Viking HL195	-40°F to +350°F, Catalog Data
• Metering Pump, Milton Roy FR-251-144	+15°F to +50°F, Meropa No. 1 above +50°F, Meropa No. 2 (Catalog Data) -25°F to +15°F, Dexron Transmission Fluid.* * Mfgr. states limit dictated by lube viscosity. Dexron transmission fluid has similar viscosity at low temp. range that Meropa 1 & 2 have at higher temp. ranges. After coordinating this with pump Mfgr., contractor recommended the transmission fluid for low temp. operation. (See Viscosity/Temp. Graph)
• Tach Generator System (Pump Speed)	-67°F to +212°F, Catalog Data.
• Hose Reel, Hannay Part Number 7024-33-34-20	-20°F to +210°F, Catalog Data. Mfg. verbally confirms equipment capability to operate at -25°F. Swivel joint -40°F to +440°F, Catalog Data
• Hose – Gates 42HW – Parker K9 101 – Title Flex CC Series	Similar to 45 HW (-40°F to +150°F) -100°F to +450°F, Catalog Data -65°F to +275°F -65°F to +450°F +450°F
• Ball Valves, Worcester 600	-50°F to +450°F, Catalog Data.
• Ball Valves, James Bury all Series	Mfg. verbally confirms satisfactory operation to -25°F
• Relief Valve, Republic 6418 Series	-65°F to +225°F, Catalog Data

Figure B-3: PROOF OF EQUIPMENT CAPABILITY AT MINUS 25°F TO PLUS 125°F (REFERENCE CONTRACT PARAGRAPH 1.16.3)

APPENDIX C

VENDORS

The various suppliers of surfacing materials and manufactured plumbing system components are presented in Figure C-1. In the majority of cases the items and vendors listed supplied materials and components used in both the high and low rate surfacing systems. Items used on only one of the two surfacing systems are noted in the remarks column of Figure C-1.

ITEM	VENDOR	REMARKS
Polyester Resin: RS50129 (RS 500 SC19-143) 26540	PPG Ind's Inc. Room 100 500 Office Center Bldg. Fort Washington, Pa. Hooker Durez Division North Tonawanda, N.Y.	
Catalyst S-0046 Green	Noury Chemical Corporation 2153 Lockport—Olcott Rd. Burt, N.Y.	
Laminac Promoter 410 100% Active DiMethyl Aniline	American Cyanamid Corporation Wallingford, Conn.	
Methylene Chloride	Great Western Chemical 6900 Fox St. S Seattle, Wa.	Commercial Item Locally Available
Tote Boxes	Seattle Box Company 401 S. Spokane Seattle, Wa.	
Fiberglass Reinforcement FABMAT C-4020 FABMAT C-2415 FABMAT C-1610	Fiberglass Industries Amsterdam, N.Y.	
Resin Pumps Solvent Pumps	Viking Pump Company Cedar Falls, Iowa	
Catalyst and Promoter Pumps	Milton Roy Company Philadelphia, Pa.	
Flexible Resin Hoses	Tite Flex, Div. Atlas Corp. 603 Hendee St. Springfield, Mass.	
Blenders	Kenics Corp. 1 Southside Rd. Danvers, Mass.	
Shut-Off Valves	Worcester Valve Company W. Boylston, Mass.	
	James Bury Corporation 640 Lincoln St. Worcester, Mass.	Supplier for Motor Driven Resin Valves - High Rate System
Swivel Joints Kamvalock Adapters and Couplings Resin Strainers	Dover Corp., OPW Division 2736 Colerain Ave. Cincinnati, Ohio	
Resin Selector Valve	Xomox Corporation Cincinnati, Ohio	High Rate System
Spray Nozzles Solvent Spray Guns	Spraying Systems Co., Inc. 3201 Randolph St. Bellwood, Ill.	
Check Valves	Durable Mfg. Company 114 Liberty St. New York, N.Y.	
	Check-All Valve Mfg. Co. 520 Elm St. Des Moines, Iowa	Resin Check Valves High Rate System Only
Relief Valves	Republic Mfg Co. 15655 Brook Park Rd. Cleveland, Ohio	Promoter – Low Rate System
	Kunkle Valve Co. 101-125 S. Clinton St. Ft. Wayne, Ind.	Promoter – High Rate System
	Farris Engr. Corp. 400 Commercial Ave. Palisades Park, N.J.	Catalyst - High Rate System

Figure C-1: VENDORS